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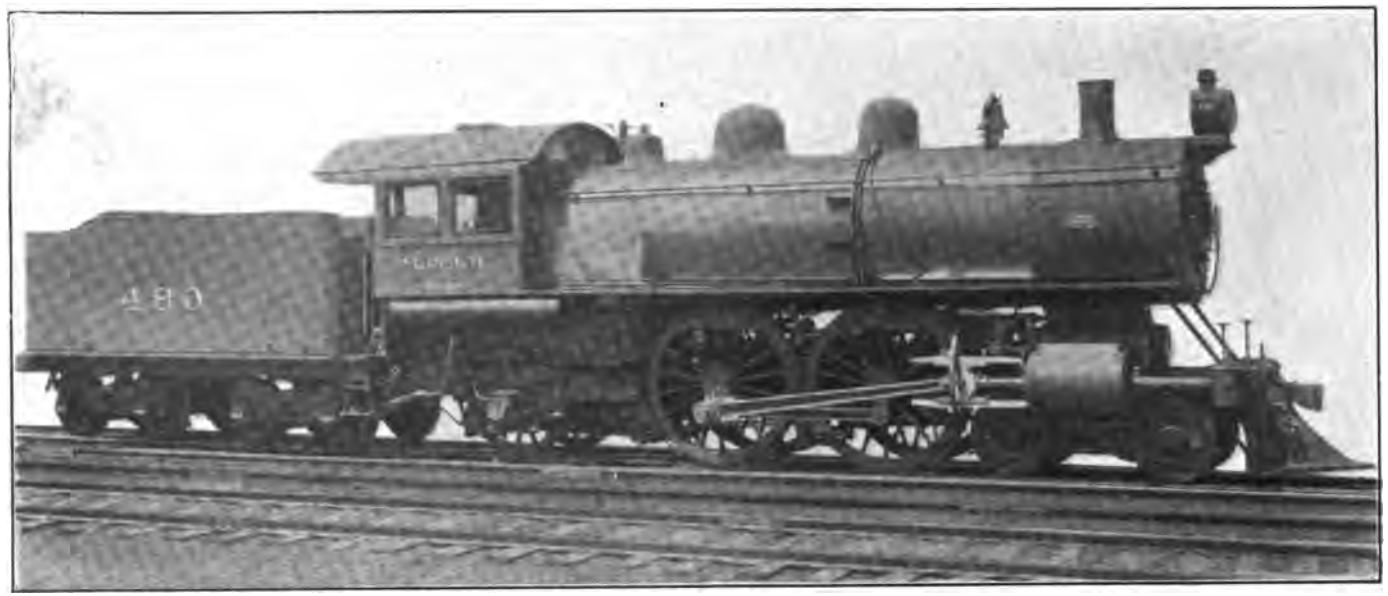

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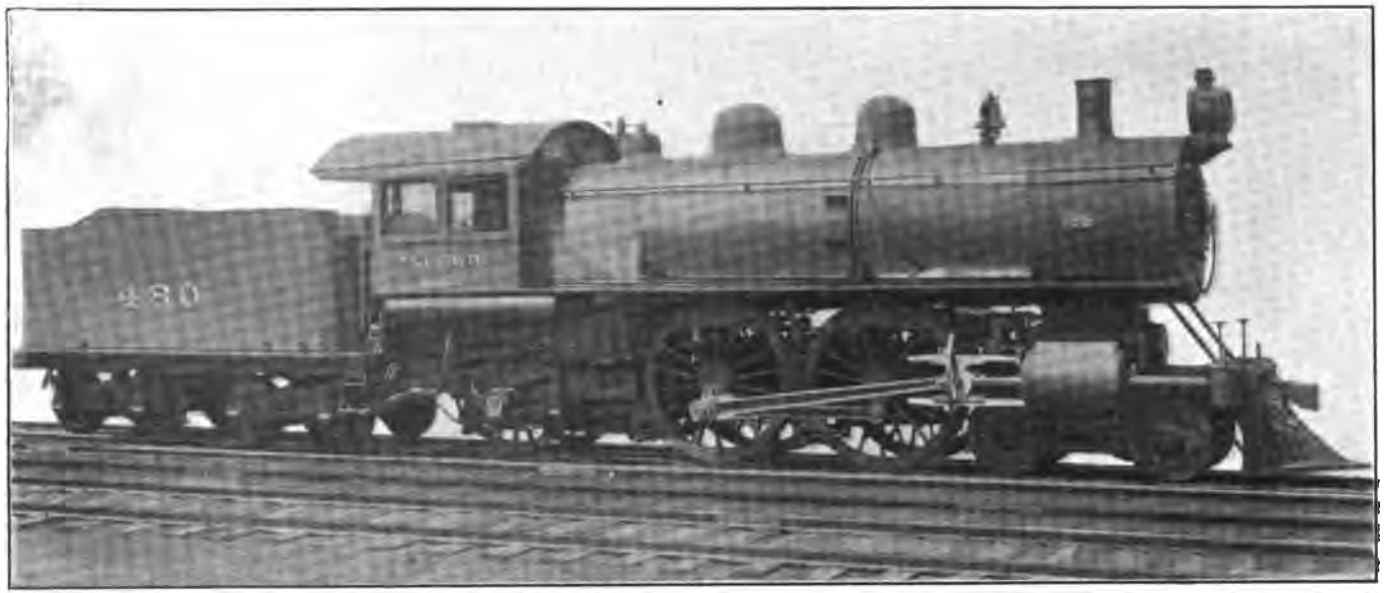

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VOLUME III.

FOUNDRY-FORGE-MACHINE SHOP

AMERICAN SCHOOL of CORRESPONDENCE at ARMOUR INSTITUTE of TECHNOLOGY

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Volume III.

PATTERN MAKING
FOUNDRY FORGE MACHINE SHOP
TOOL MAKING

SECTION I.

PATTERN MAKING.

Pattern making dates back to the time when the first article was made from molten metal for the use of man. The pattern must precede the making of its metal counterpart, and is, therefore, the first subject to be treated in the working of metal.

Qualifications of the pattern maker. The pattern maker is essentially a worker in wood, though where many pieces are to be cast from a single pattern it is frequently made of metal. He should, however, possess an intimate knowledge of the properties of metals. First of all, he must understand the **shrinkage** of metals, that is to say, how much smaller the cold casting will be than the molten mass as it flows into the mould; he should know what the **strength** of the metal is; he should be familiar with the relative **rapidity of cooling** so that internal stresses in the body of the completed casting may be avoided as much as possible; he must also know enough about the practical work of the moulder to decide upon the peculiarities of construction of the pattern for any given piece; and he must be enough of a **draughtsman** to lay out the drawings of the piece to be made without the assistance of the designer. It is very true, however, that there are many pattern makers who do not possess all of these qualifications.

The last mentioned qualification is one of the most important. The drawings furnished the pattern maker are usually on a small scale, and in order to work to the best advantage, he is expected to reproduce a part or all of them in full size upon a chalked board. This does not require the same nicety and precision of workmanship that is called for in the drawing room; but it is essential that the pattern maker have the same complete knowledge of the principles involved. To the extent, then, of being able to make a full size drawing of the article to be made, upon a chalked board, the pattern maker must be a draughtsman.

In large establishments where all work comes to the pattern shop as carefully executed drawings, the pattern maker is the means of putting the ideas of others into a tangible form. In smaller places, where no draughtsman is employed, the pattern

maker will be called upon to work out the designs from which he is to make his patterns and he thus becomes the real *designer*.

Finally, the pattern maker is seldom required to make two patterns that are identically the same. His work is, therefore, varied and he must be prepared to apply to the solution of new problems, such principles as he may have learned.

Materials for Patterns. As patterns are subjected to more or less rough usage, and are alternately wet and dry, it follows that the ideal material is one whose hardness is such that it can withstand the wear and tear of handling, and at the same time be impervious to the effects of moisture. Such a material is to be found in the *metals* but, as the cost of working them into the proper shape is considerable, some kind of **wood** is usually substituted.

Kind of Wood Used. If, then, wood is to be used, another qualification is to be added, namely, it should be easily worked. The best wood for the purpose is undoubtedly **white pine.** It can be obtained with a straight grain and free from knots. In choosing the wood, that which comes from the Northern States or Canada and has grown upon high ground, will be found to be the most satisfactory. Care should be exercised in the inspection of the wood, that it is *clear*, *straight grained* and *free from knots.*

The straightness of the grain can be determined by the appearance of the sawn face. This should present an even roughness over the whole surface. It should be seasoned in the open air but preferably sheltered by a roof and be piled so that the air has free access to all parts of the stick. Kiln dried lumber is likely to be brittle and does not work as easily as that which has dried more slowly in the open air. If the selection is to be made for any special work, the size of the timber should be proportioned to the place in which it is to be used, but for general pattern work, planks two inches thick will be found a convenient size. Lumber of this thickness can be properly dried and is also large enough for almost any pattern. It has the further advantage of not checking or cracking as easily as thinner stock.

Pine, however, is soft and weak so that, if small and strong patterns are desired, a harder wood is usually employed. *Mahogany* is the most suitable for this purpose, and the same care should be

exercised in its selection as in the case of pine. Genuine mahogany, straight grained and free from defects, should be used and not the cross-grained bay wood that is often sold in its stead.

Cherry is also extensively used and black walnut, beech, and maple to some extent. Black walnut is brittle and may crumble; beech and maple are likely to warp.

It may be stated, then, that, in the United States, white pine is the material commonly employed for pattern making.

Warping and Twisting of Wood. Observation shows that if one side of a piece of wood is kept damp and the other dried, the former will *expand* and the latter *contract* so that the piece which was originally straight becomes curved as in Fig. 1. A common example of this is to be found in the planking of a board sidewalk, where the upper surface is exposed to the drying effects of the sun, and the lower to the moisture arising from the ground. It requires more time under the same conditions for a large piece of timber to become dry than it does for a small piece; because the moisture at the center has farther to travel before reaching the surface. Hence, small pieces cut from a large stick that has been seasoning, will not possess the same degree of dryness throughout their respective masses. If two of these pieces are fastened together the combination will *warp* as a result of the drying of the damper piece. It is well, therefore, when making a pattern to get out all of the pieces and allow them to season for a while so as to avoid warping.

Fig. 1.

Tools. The tools of a pattern maker's kit do not differ essentially from those of a carpenter who is doing first-class work. While it is impossible to give a list of all the tools that a pattern maker may find convenient, the following are the more essential.

Saws, — cross-cut, rip, and miter.

Planes, — jack, jointing, smoothing, compass, rabbet, and core box.

Chisels, — firmer and paring of various widths.

Gouges, — firmer and paring of various sizes, both concave and convex.

Squares, — fixed and bevel.

Gages, Compasses, Trams, Calipers, Mallets, Hammers, Screw-drivers,, Pliers, Spoke shaves, Brad awls, Oilstone, Scriber, Standard and Contraction rules, and Clamps.

Saws. Cross-cut and rip saws: these two kinds of saws are

Fig. 2.

as their names indicate, for cutting across the grain and ripping with the grain of the wood, respectively. Their general appearance is shown in Fig. 2. The difference between them is the shape of the tooth. It is to be noted that nearly all

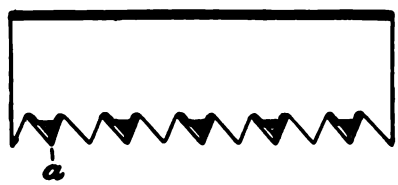


Fig. 3.

Fig. 4.

Fig. 6.

woodworking tools do the cutting as they are moved away from the workman. The cross-cut saw has a tooth with the front or cutting edge inclined back from the front, with the two edges beveled to form a cutting edge as shown at *a* of Fig. 3. The alternate teeth of the cross-cut saw are beveled on opposite sides as shown in Fig. 3. In addition to this, the alternate teeth are given a set as indicated by Fig. 4 at *a* and *b*. This set causes the saw to cut a wider slot or kerf in the wood than the back of the blade and thus prevents the material from pinching.

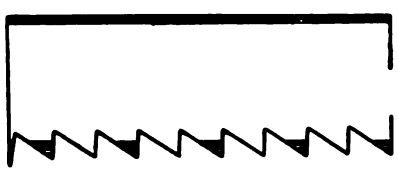


Fig. 5.

The front edge of the teeth of a rip saw are at right angles

to the line of the blade and are sloped back as shown in Fig. 5. They have no set as in the case of the cross-cut, but the points are broadened or swaged out by hammering as in Fig. 6. In this case the kerf is the width of the swaged points.

A cross-cut saw can be used for ripping, but it is exceedingly difficult to use a rip saw as a cross-cut.

Fig. 7.

Miter saws are used for sawing joints and miters across the grain. The teeth are usually very fine and the blade is stiffened by a heavy strip of metal along the back edge. It is illustrated by Fig. 7.

Planes. The jack plane is used for removing the rough surface of the timber as it comes from the saw and thus preparing it for the jointer and smoothing planes. The stock of the plane is usually made of beech though it is sometimes of metal. The blade

Fig. 8.

or plane iron is of steel and is often made in two pieces; one the cutting blade and the other a strengthening piece or cover held to the former by a screw. The blade is held in position in the stock by a wedge which is usually made of wood. The blade should be ground slightly rounding on the corners so that they will not dig into the material for the pattern. The sharpening should always be done on the *bevel* face of the knife and not upon the flat sur-

face. This applies to all wood-cutting tools. After the iron has been sharpened the cover should be screwed on, the iron projecting a very short distance below it, as in Fig. 9. The whole is then put in the mouth of the plane and adjusted with the wedge, so

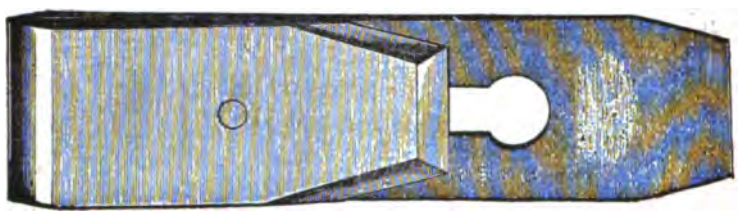


Fig. 9.

that the blade projects a short distance (about $\frac{1}{64}$ inch) below the face of the stock. By looking along the face of the stock the amount of the projection is seen and if it should be too much, a light blow on the top of the plane at the front end will drive the iron back. The amount of the projection determines the thickness of the shaving.

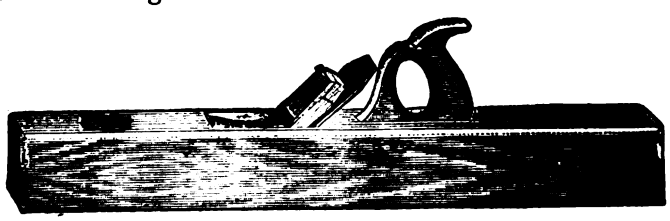


Fig. 10.

Jointing Plane. This plane resembles the jack plane except that it is longer, and, therefore, gives a greater surface for straightening. It is shown in Fig. 10. The iron is ground the same as in the case of the jack plane, except that the rounding should not extend in for more than from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch from the edge. The projection of the blade below the surface of the stock is also less than in the case of the jack plane.

Smoothing Plane. This plane is shorter than either of the others. The blade should be sharpened and set like the jointer.

It is used for *smoothing* a surface rather than for *truing* it. The plane is illustrated by Fig. 11.

Compass Plane. This tool resembles the smoothing plane except that the working surface is convex instead of flat. It is used for smoothing concave surfaces where the curvature runs with the grain of the wood. It is shown in Fig. 12.

Fig. 11.

Fig. 12.

Rabbet Planes are tools whose sole or working face has a shape to conform to the surface of the work to be done. They may, therefore, be of an infinite variety of forms, but the two in most common use are the narrow convex and the concave as illustrated by Figs. 13 and 14. The flat sole, as shown in Fig. 15, is also frequently added to the kit. The use to which these planes are most extensively applied is the making of mouldings and fillets.

Fig. 13.

Core-box Planes. The working out of cylindrical core boxes is of every day occurrence in all pattern shops. This is done by first roughly shaping the work with a gouge, then bringing it to a circular shape with a core-box plane, and finally smoothing with a round-soled plane, Fig. 16. The core-box plane, Fig. 17, is constructed upon the principle that two chords drawn from any point on the circumference of a circle to the opposite extremities of any diameter, form a right angle with each other. Such a plane is

shown in Fig. 17. The two sides forming the soles are at right angles to each other, and have a knife or plane iron in the corner. The method of using is as follows; one-half the core box is roughed out with the gouge as shown in Fig. 18. The points *b* and *d* on the edges of the groove are cut away as in the finished box and are made exactly to size throughout the entire length. Stock is left below for removal as shown by the solid line. The finished core is to correspond to the dotted semi-circle. The plane is so placed that the sides occupy the position shown by the two full lines *a b* and *b c*, and these faces always kept in contact with the edges *b* and *d*. As the plane cuts away the surplus material its sides will occupy the positions indicated by the angles *a' b' c'*, *a'' b'' c''*, etc., until the whole semi-circle has been cut out and the box is ready for smoothing. This plane can only be used when its sides are greater in length than the diameter of the core.

Fig. 14.

Chisels. Two kinds of chisels are used by the pattern maker, the *firmer* (Fig. 19) and the *paring* (Fig. 20.) The firmer chisel is intended for heavy work with the mallet, and to prevent splitting, the handle is usually set in a socket which is a part of the blade. The paring chisel is longer, lighter in the blade, and is sharpened with a keener edge and a longer bevel. Every pattern maker should possess an assortment of these chisels of widths varying from $\frac{1}{8}$ inch to $1\frac{1}{4}$ inches.

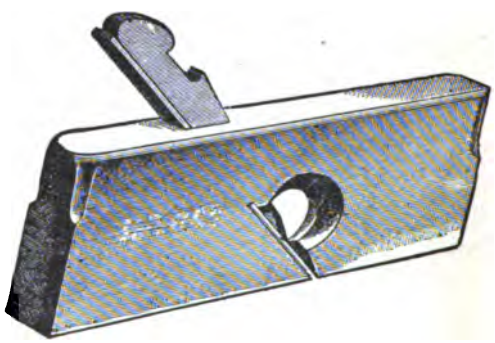


Fig. 15.

Gouges. What has just been said of chisels applies equally well to gouges, an example of which is illustrated in Fig. 21. Gouges are made with the bevel of the cutting edge on both the convex and the concave sides, though the former method is the more common.

Fig. 16.

Squares. The square is one of the most important of the pattern maker's tools, for upon it depends the accuracy of his work. The usual form of try-square is shown in Fig. 22. It is advantageous to have a number of these squares, of different sizes, in the kit. Those with blades 4 inches, 8 inches, and 12 inches in length will be found to be the most convenient.

Fig. 17.

T bevels. As the wood of patterns is not always to be cut at a right angle, it is necessary that a tool should be provided for measuring acute and obtuse angles. The T bevel illustrated in Fig. 23 answers this purpose. For convenience in adjusting to small or cramped spaces a slot is cut in the blade. By means of this slot and a set screw the blade is moved and clamped in any desired position and at any angle.

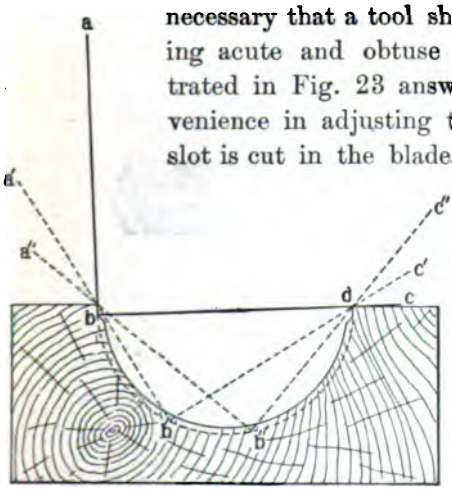


Fig. 18.

Gauges. The gauge (Fig. 24) is used for drawing a line at a given distance from and parallel to an edge of the wood. The head *a*, slides on the stem *b*, and is held in any desired position by the thumbscrew *c*.

Fig. 19.

Fig. 20.

Fig. 21.

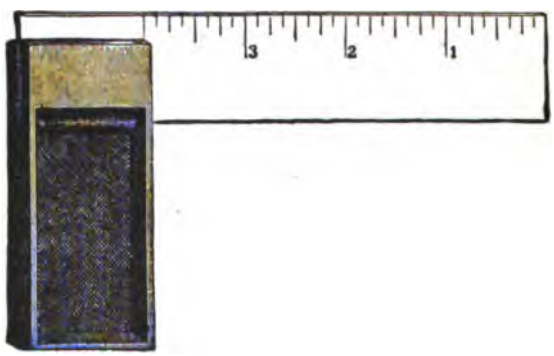


Fig. 22.

Fig. 23.

In setting the gauge the adjustment is made so that the distance from the cutter *d* to the groove in the head *a* is equal to that at which the line is to be drawn. The groove is run along the edge of the wood and the cutter marks the desired line. Various forms of the gauges are in use, some having a scale showing the distance from the cutter to the groove, but the one shown is the ordinary form.

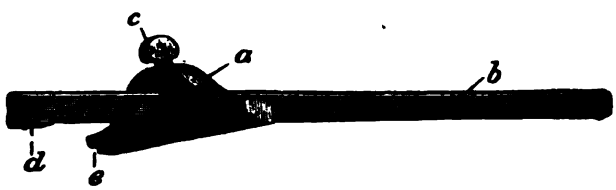


Fig. 24.

Fig. 25.

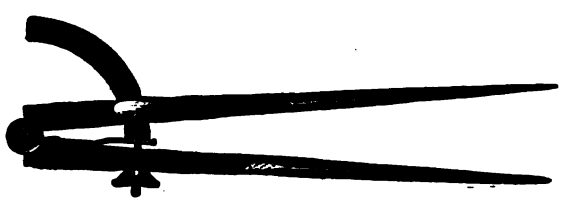


Fig. 26.

Compasses and trams. These instruments are used for describing the arcs of circles of given dimensions. The compass consists of two legs pointed at one end and pivoted together at the other. The pivot may be tight and the legs held in any set position by friction as in Fig. 25, or loose and held by a thumb screw in one leg, bearing against a wing or quadrant fastened to the other leg as in Fig. 26. Such compasses are sometimes provided with an adjusting screw, working on a spring, for facilitating the setting of the legs. Trams are merely large

compasses used where the distances between points are so great that the legs of the compass will not reach. Trammel points are fastened to a beam of sufficient length to enable them to be set at the desired distance apart. Such a tram is shown in Fig. 27. The body of the trammel is held to the beam in any position by the thumbscrews at the top.

Fig. 27.

Calipers are made like compasses but with legs so shaped that they can be used for measuring the inside or outside diameter of a circular body, or the distance between two points where it would not be convenient to use a rule. Figs. 28 and 29 illustrate a pair of inside and outside calipers respectively. The points of the former are turned outward so as to come in contact with the inside surface of the work, while the reverse is the case with the outside calipers.

Hammers and mallets. The ordinary form of hammer is that given in Fig. 30. Each kit should contain three or more of these tools of varying sizes, to be used according to the work in hand. The weights of heads range from 7 to 20 ounces. The mallet is used for driving the firmer chisels and gouges, and for striking surfaces that must not be marred. The head may be square, as in Fig. 31, or round.

Small Tools. Screw drivers, Fig. 32, are used as their name indicates. As they are bought the end of the blade is usually ground on a straight bevel as in Fig. 33. The user will, however, find it advantageous to regrind it so that it has the form shown in Fig. 34. By so doing the tendency of the driver to slip out of the slot of the screw is lessened because the square side of the driver bears against the square side of the slot of the screw. The kit should contain several sizes of this tool with blades ranging in length from 4 to 10 inches.

Fig. 28.

Fig. 29.

Fig. 30.

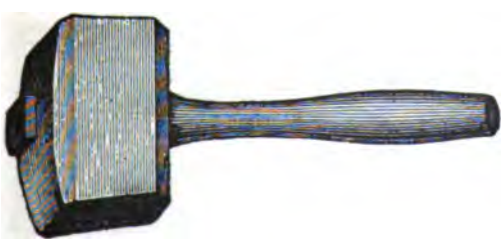
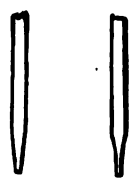


Fig. 31.

Pliers are used for holding small objects that cannot be conveniently held in the hand; for bending wire, etc. The common shape is shown in Fig. 35.

Fig. 32.

Bradawls are for the purpose of making small holes into which nails or screws are to be driven. An ordinary form is shown in Fig. 36.



Figs. 33 & 34.

Oilstones serve to give a smooth, keen edge to the tool, after it has been ground. The Turkish stone is usually considered to be the best, but it is expensive. The stone ordinarily used in this country comes from Arkansas. A convenient size will measure 6 inches by $1\frac{7}{8}$ inches or 8 inches by 2 inches. These should be

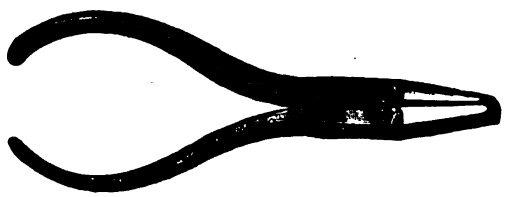


Fig. 35.

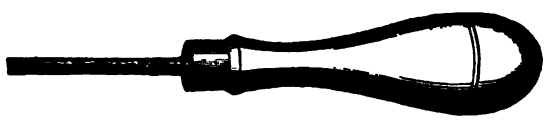


Fig. 36.

Fig. 37.

mounted in a case with a cover to protect them from the dust when they are not in use. It is also desirable to have a piece of

Views of the Oliver Universal Saw Bench.

leather on the top of the cover for a final whetting when an especially sharp edge is required.

Scribers or **Scratch awls** (Fig. 37) resemble brad awls except that the end is pointed. They are used for marking on wood and laying out work.

Rules. For ordinary measurements the pattern maker needs a two-foot folding rule similar to those carried by carpenters and other workmen. For laying out and taking the dimensions of patterns a **shrinkage rule** must be used. When a mould is filled with molten metal the temperature of the latter is very high, and as it cools and solidifies, it contracts. The pattern maker must, therefore, compensate for this by adding to the size of the pattern.

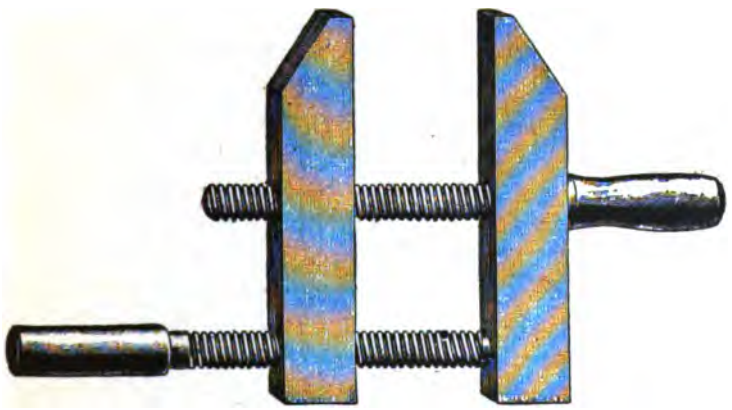


Fig. 38.

In order that this may be done and exact relations be maintained for all dimensions, a shrinkage rule is used. This rule is marked off exactly like an ordinary rule, but if the two are compared, the former will be found to be about $\frac{1}{8}$ inch longer for each foot of length. These rules are usually made of a single straight length of beech or boxwood $24\frac{1}{4}$ inches long and are graduated as though they were *exactly* 2 feet. In using the shrinkage rule, the workman proceeds as though he were using a standard rule, and when the pattern is completed it will be found to be $12\frac{1}{8}$ inches long for a 12 inch casting. All other dimensions will be larger in the same proportion.

Clamps. Every pattern shop should be equipped with a number of clamps or handscrews similar to that shown in Fig. 38.

These clamps are adjustable through wide ranges and are used for holding pieces together that are being glued or for other purposes. A special form is the C clamp, shown in Fig. 39.

Fig. 39.

In the use of all cutting tools, especially paring chisels, gouges, and planes, particular attention should be paid to the grain of the wood. Where the grain does not run exactly true with the piece as in Fig. 40, the plane or chisel should be moved so as to cut in the direction of the arrow. This smooths down the grain and the tool has a tendency to run out. But, if the cutting is done in the opposite direction the tool tends to dig into the wood, taking a shaving of increasing thickness and finally causes splintering.

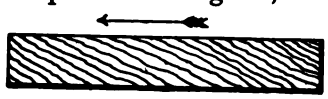


Fig. 40.

Machinery. The machinery used in a pattern shop varies with the size of the establishment and the number of men employed. It is not necessarily the same as that in an ordinary wood-working shop but it is of the same character. The one machine that is indispensable is the lathe.

The Lathe. This useful machine (Fig. 41) should be carefully made and rigid in all its parts. As the pattern shop is usually upon an upper floor, where the machinery must be placed upon joists, it is essential that the lathe itself should possess all the requisites of rigid construction, in order to avoid the vibration that would otherwise result from running it at a high speed. The legs and bed should be of iron and the head stock carefully fitted and firmly bolted in place. The spindle should be of steel and carefully fitted in phosphor bronze bearings. When there is

only one lathe in a shop, it should be of such size that it can swing pieces at least 12 inches in diameter and 6 or 7 feet long. The headstock should be made reversible and the face plate be made to overhang the bed, thus making it possible to turn work of large diameter. Or, better still, the spindle should be extended through the outer box and fitted for the attachment of a face plate. The lathe should be driven by a **cone pulley**, that is made as light as possible, and whose size should be such that a speed of at least 1,400 revolutions per minute can be obtained when the belt is driving on the smallest pulley of the cone. This will give a rate of revolution, when the belt is on the largest step of the cone of about 350 per minute.

Fig. 41.

Closely connected with the lathe are the **chucks** for holding the work. The end of the spindle should be cut with a screw thread upon which a **face plate** may be screwed and it should also be made hollow and tapering for the reception of a fork **center.** The latter is used for driving work that is run upon the dead cen-

ter of the tailstock and also serves as a live center, carrying one-half the weight of the piece. It is shown in Fig. 42. Another simple method of driving is called the screw drive. This is a chuck cut with an internal screw to fit that on the lathe spindle

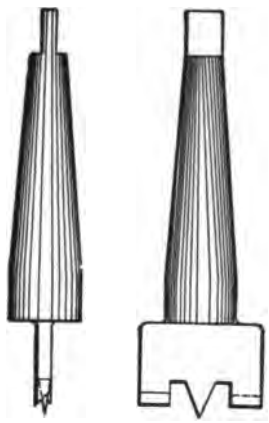


Fig. 42.

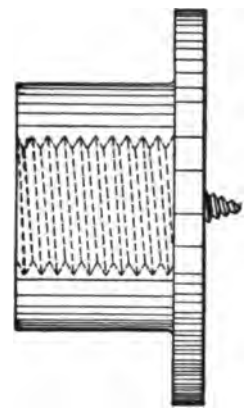


Fig. 43.

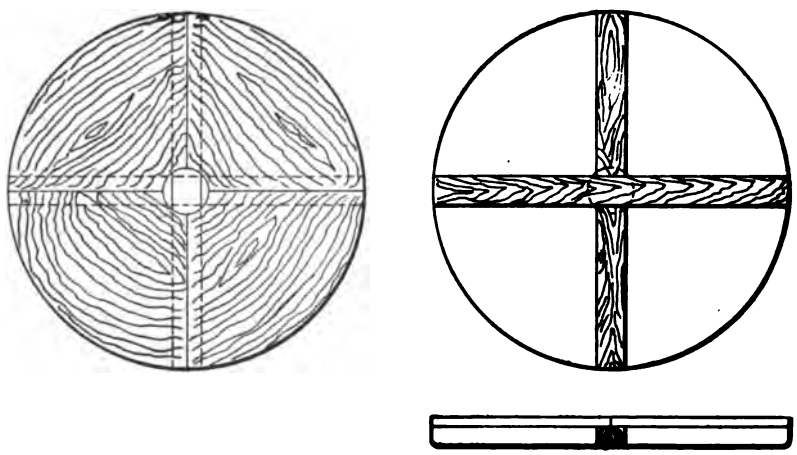


Fig. 44.

and having a coarse wood or machine screw projecting from the front face. It is used to hold light work that is short and of small diameter. It is shown in Fig. 43 and it will be seen that the piece to be operated upon is simply run upon the screw.

For work of large diameter face plates are necessary; these are usually made of wood held by screws to a flanged coupling which is screwed upon the spindle. The plate itself may be a piece of board for small diameters or it may be built up as shown in Fig. 44.

The **tool rest** is usually T-shaped and made to slide freely along a groove at the front of the lathe bed. It should be easily and quickly fastened in position either by a wedge or cam involving only a single blow from a hammer or one motion of the hand.

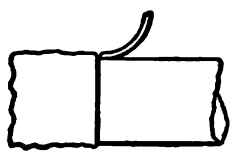


Fig. 45.

On long lathes and in shops where columns and pipes are to be turned, it is well to provide a sliding carriage in which the tool is fastened. The carriage may be moved by a rack and pinion parallel to the center line of the lathe. This makes it possible to do straight work more rapidly than can be done by hand tools.

Hand tools. When a piece of work is put in the lathe the **roughing cut** is invariably taken with a **gouge.** The turning gouge differs from the one already described in that it is heavier

Fig. 46.

and is ground somewhat differently. In grinding a turning gouge it is cut away more on the sides than at the center so that the angle of the bevel may be the same. In using this tool the hand rest is set so that it clears the revolving work by about a half an inch. The gouge is held in both hands, one grasping the blade near the hand rest and the other the end of the handle. In taking a roughing cut the gouge should be tilted to one side, the advancing edge being the lower. If this precaution is not taken the tool will tend to rip into the work. The position of the gouge is illustrated by Fig. 45.

The gouge may be and is extensively used for finishing but the **skew chisel,** Fig. 46, does better work although it requires more

skill to manipulate. It is held very slightly inclined to the work and is fed in the direction of the inclination which should always be toward the short edge of the blade.

For **finishing**, an ordinary square chisel is frequently used. With this tool as well as with the gouge and skew chisel the hand rest should be set so that its upper surface is about level with the center of the work. The square chisel is held level while the other two are given a slight upward inclination. The square chisel thus becomes a scraper and should not be required to remove very much material. The shape of this tool is sometimes modified so as to have a rounded or angular cutting edge.

The grindstone. Second in importance to the lathe in the power-driven tools of the pattern shop is the grindstone. A good close-grained Huron stone of about three feet in diameter, when new, is suitable. The stand should be provided with ample facilities for keeping the stone wet. A very satisfactory arrangement is a $\frac{1}{2}$-inch water pipe terminating in a T-head with valve for controlling the flow. Shields are sometimes used to prevent the water from spattering and a cast iron sink is placed underneath. The grindstone ought not to be neglected but the bearings should be kept well lubricated and the outside true. No stone can be found of an absolutely uniform hardness, and, as the pressure and surface presented by the tool varies from second to second, the stone soon loses its cylindrical shape. It should then be turned true, an old file being an excellent tool for the purpose.

Fig. 47.

In using the grindstone it is better to stand so that the stone runs away from the cutting edge as shown in Fig. 47. This method is less likely to cause hollows to be cut in the stone and is also easier. After grinding, the **feather edge** rolled back on the cutting edge should be wiped off on the hand or piece of pine and the final sharpening be done on an oil stone. The flat face of the tool should be rubbed lightly over the stone to remove the last traces of the feather edge and then keenness added by rubbing the bevel. The finishing touch may be put on by stropping the tool on leather.

Saws. The lathe and the grindstone are the two essentials

of a pattern shop, but it is very desirable that they should be supplemented with a **circular saw table.** This table may have one or two arbors. If there are two, one should carry a rip and the other a cross-cut saw. The latter is the most convenient as such tables are made so that either saw can be instantly raised to the cutting position or as quickly lowered. The table should also be provided with an adjustable and removable gauge or fence so arranged that

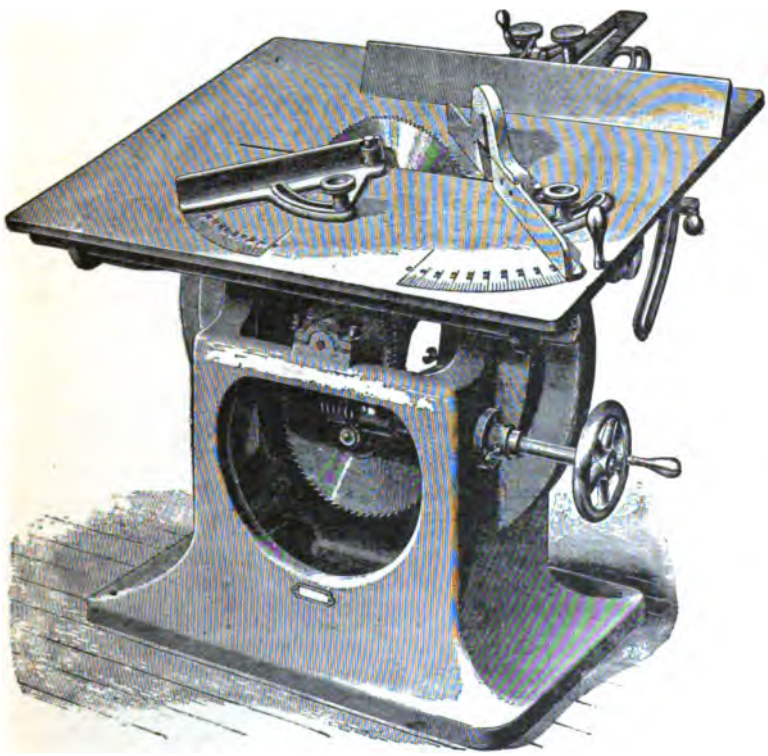


Fig. 48.

it may be easily taken away; thus leaving the whole upper surface of the table clear. It should also be possible to set it at any angle for beveling, gaining, etc. A convenient table of this kind is shown in Fig. 48. The size of saw that is best suited for the ordinary pattern shop is about 10 inches in diameter and should be made to run about 2,500 revolutions per minute.

The next tool to be placed in the pattern shop is the **band** or

jig saw. These two types of saw are intended for doing about the same class of work. They may be used to cut scrolls and curves and thus save much necessarily slow handwork. The band saw has the advantage of more rapid and smoother cutting while

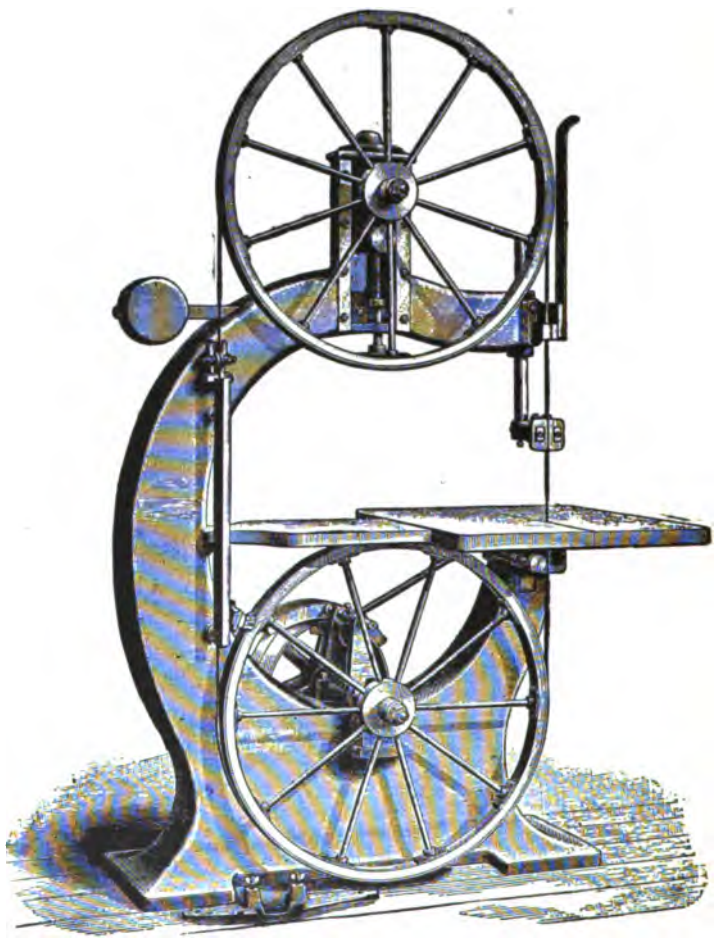


Fig. 49.

the jig saw can be used on the interior of closed curves. It is, however, possible to use the band saw for this work by cutting through the solid material and then gluing a thin strip in the kerf to close the opening thus made. In band saws the pulley

wheels should be large, light, and carefully balanced. They should be large so as to prevent breakage due to the bending of the saw to a small radius; they should be light so that their momenta may

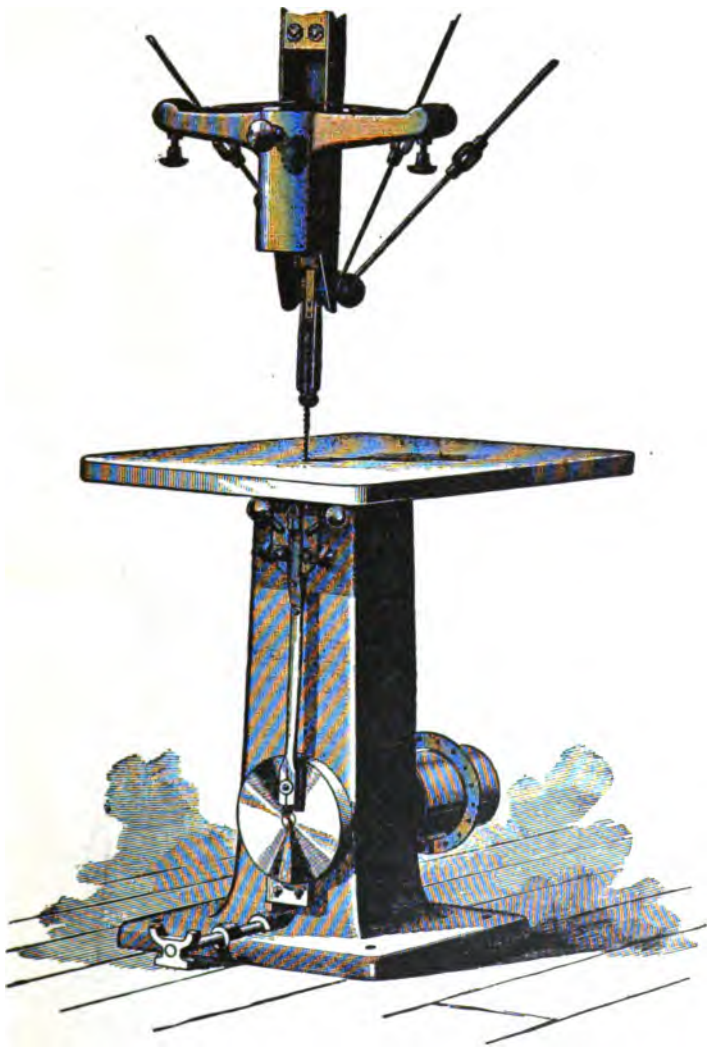


Fig. 50.

not cause over-running, producing a buckling and breakage; and they should be balanced to avoid jar and a strain on the saw when the bearings become worn. The cutting speed of the saw should be

about 3,500 feet per minute. Fig. 49 illustrates a well-designed saw.

A convenient width of saw and one which will answer for all general purposes is $\frac{5}{8}$ inch. As breakage is apt to occur, the pattern maker should be able to repair the saw by *brazing*; a kind of work that will be described later in the course.

The **jig saw** (Fig. 50) works more slowly than the band for the two-fold reason that the speed is less and the cutting takes place only during the downward stroke. The usual method of construction is to fasten the upper works to the ceiling, leaving the

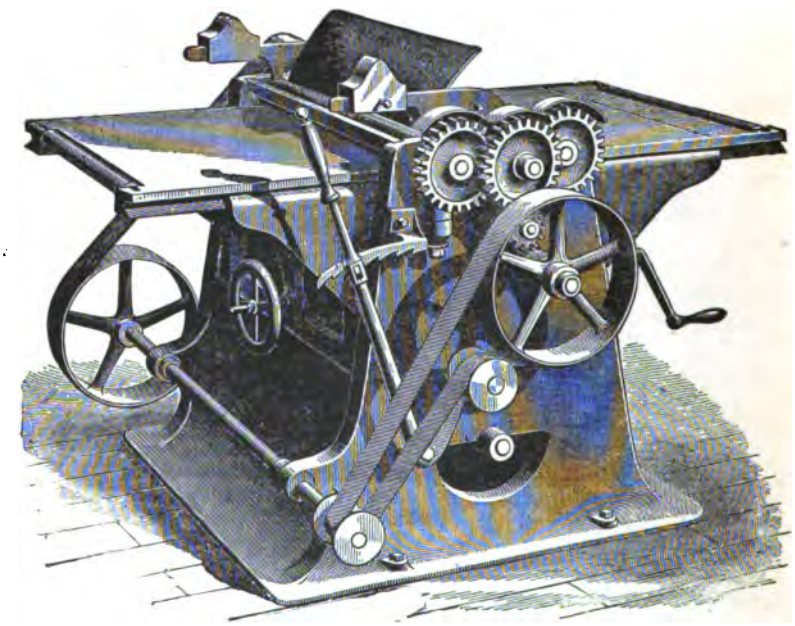


Fig. 51.

whole surface of the table clear for any size of work. This upper portion consists of a spring and guide to which the saw is attached and by which the up stroke of the latter is made. Beneath the table there is a crank and connecting rod driving a crosshead to which the lower end of the saw is fastened. The means of attaching the saw to the upper slide should be in the form of a hook or some other simple contrivance so the blade may be easily

disconnected for placing or removing the work. The speed of the machine should be about 1,100 strokes per minute and the length of stroke should be about 6 inches. The width of saw may vary from $\frac{1}{4}$ inch to $\frac{5}{8}$ inch.

Where one saw for scroll work is installed it is usually the *jig* or *fret saw*.

Planing Machine. This is a valuable machine but is one that does not find a place in every shop. It is used for dressing lumber to convenient thickness. The ordinary surface planer will not, however, take the twist out of timber, but merely smooths

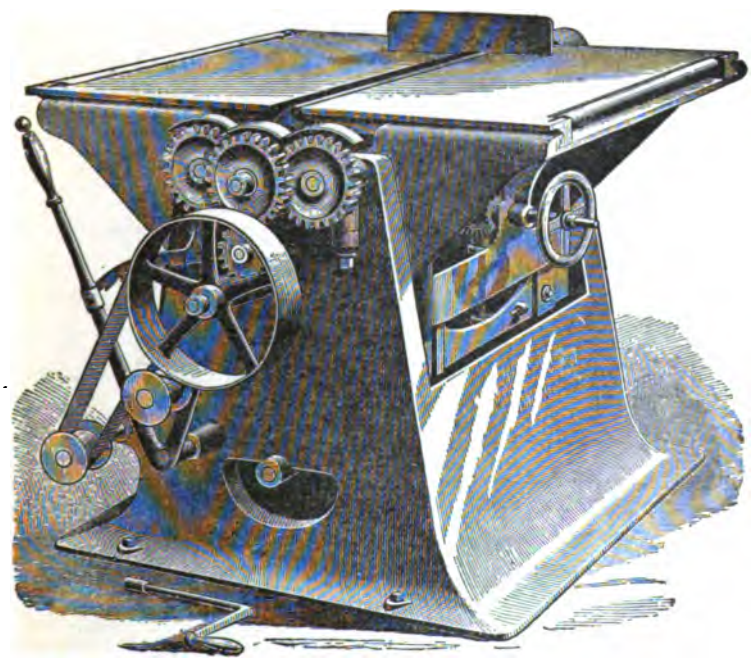


Fig. 52.

and brings it to an even thickness. It works rapidly and its knives should be driven at a speed of about 2,500 revolutions per minute.

A convenient form of this machine is shown in Figs. 51 and 52. It is so arranged that it can be converted from the planer (Fig. 51) to the jointer (Fig. 52) by merely raising the table. The jointer can be used to take the twist out of material that is

warped and the planer afterwards put into service for bringing it to the thickness desired.

Universal Trimmer. This tool (Fig. 53) is one that, of late years, has become very popular in the pattern shop. It will cut any sides or ends within its capacity, and an end that would take from ten to fifteen minutes to square properly with a square and chisel can be finished in as many seconds with this machine. The cutting is done with remarkable smoothness and requires no sandpapering to prepare it for varnishing. The machine is operated by hand. The table is fitted with gauges and fences so that the knives can be made to cut at any angle. The power is applied by means of a long handle to which a pinion is fastened; the latter meshes with a rack on the plate carrying the bevel knives which are moved to the right or left according to the direction of motion of the handle, the work being held against the guides at the side of the machine.

Method of Moulding. As has already been said, it is necessary that the pattern maker should have some knowledge of moulding in order that he may construct his patterns so that they can easily be removed from the sand. A brief description of the general method employed will suffice. Ordinarily a casting is made in a flask composed of two parts, each containing its complement of sand. The upper part is called the *cope* and the lower part the *nowell* or *drag*. The pattern is usually made in two pieces which part along the line separating the cope and drag. Thus in Fig. 54 the pattern separates with the flask on the line A B and when so separated the cope is turned upside down and the portion of the pattern C is lifted out. The part D is lifted out of the drag in the same way.

In the case of hollow objects, the internal cavity is formed by cores which rest in cavities of the sand made by the pattern. Fig. 55 represents a section of a flask with the mould made and core set for the casting of a hollow cylinder. The pattern was parted along its center line as before and the sand rammed in both cope and drag. Then after its removal the core A is set in position, resting upon and filling up the spaces x and y made by the core prints of the pattern. Therefore, when the metal is poured it fills the open space around A, forming a hollow cylinder.

Fig 53.

Patterns from Drawings. As already explained the pattern maker must understand working drawings in order to make full size drawings from them or construct the patterns directly. In all drawings that he receives the dimensions given will be those of the finished piece. That is to say, the drawing is a representation of the piece as it will be when completed. It has already been noted that the pattern maker must make his pattern larger than the actual piece in order to allow for the natural shrinkage of the casting in cooling. This increase of size is, however, allowed for by the shrinkage rule with which he takes his measurements. But if the piece is to be finished in the machine shop,

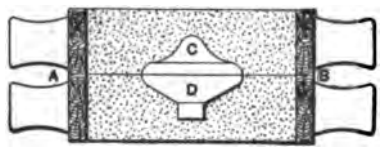


Fig. 54.

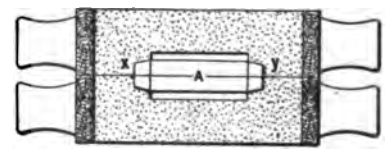


Fig. 55.

an *additional* amount must be added to the pattern in order to provide the metal that is to be removed. The amount that is to be so added is, to a certain extent, though not wholly, independent of the size of the piece. For small articles whose longest dimension does not exceed three or four feet an addition of $\frac{1}{8}$ inch to the surface to be finished is usually sufficient. For larger dimensions it may be necessary to add as much as $\frac{1}{4}$ or $\frac{3}{8}$ inch though very rarely more than this. In making this allowance it is also well to bear in mind the inclination of the piece to warp in cooling. Where the thickness of the metal varies to any great extent there is a greater liability to warp than if a uniform thickness prevails throughout the whole. Hence, in such cases a greater allowance must be made for the finishing.

On small pieces and where the moulding is carefully done it may be possible to make smaller allowance than $\frac{1}{8}$ inch, but as a general rule sufficient metal should be put upon the casting so that the cutting tool of the finishing machine may cut well below the surface and not become dulled by the sand and hard scale on the outside.

Simple Patterns. The simplest patterns are naturally those which are made in one piece and which require no coring, although

the casting may itself be hollow. The first thing which the pattern maker should decide in commencing a pattern is the way in which it is to be removed from the sand and where the parting line should be if there is to be one. As an example of a simple pattern of one piece made without a core, the stuffing-box gland of Fig. 56 is a good example.

It must be understood that in order for a pattern to *draw* out of the sand it can have no re-entering parts that can catch the sand as it is lifted. In the gland under consideration this is the case. It is readily seen that if the pattern of such a gland were to be bedded in sand as shown in the engraving there is no reason why it should not be lifted out in the direction of the arrow without disturbing any of the surrounding sand. The finished gland is to be cut to the contour of the dotted lines. It is important for these to be straight and form right angles with each other. It has already been explained that the pattern must be made larger than the finished contour to allow for the metal to be removed by finishing. This is shown in Fig. 56 by the difference between the full and the dotted lines. There is another allowance, however, that should be made. This is called the *draft* of a pattern. It will be seen that if the diameter of a pattern at *a* were to be the same as that at *b*, the latter point would drag over the whole length of the sand until it reached the former point. As the sand is held together very lightly this dragging would be likely to dislodge some of the particles and make it necessary to mend the mould. In order to avoid this, the diameter at *a* is made slightly greater than that at *b* so that the body of the gland is tapering and, the moment it is started out the whole surface from *a* to *b* is clear of the sand and can be removed without injury. This difference in the diameters at *a* and *b* is called the *draft* of a pattern. The amount of draft depends upon the length of the part that is to be drawn out of the sand. A convenient measure is to increase the diameter $\frac{1}{8}$ inch for each foot of length or add $\frac{1}{16}$ inch to each foot of flat surface.

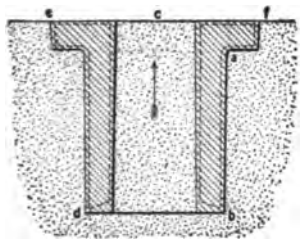


Fig. 56.

In this case there must also be an allowance for draft on the inside between *c* and *d* and also at the edges of the flange at *e* and *f*.

The pattern shown is entirely embedded in the sand of either the cope or drag though it would usually be moulded in the latter. It is quite possible, however, to have a pattern in one piece imbedded in the sand in both cope and drag. Such a pattern is to be found in the journal brass used on railroad car axles, as shown in Fig. 57.

Hereafter no reference will be made to the allowances for

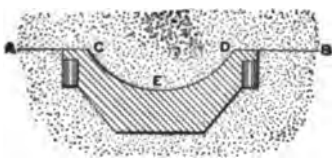


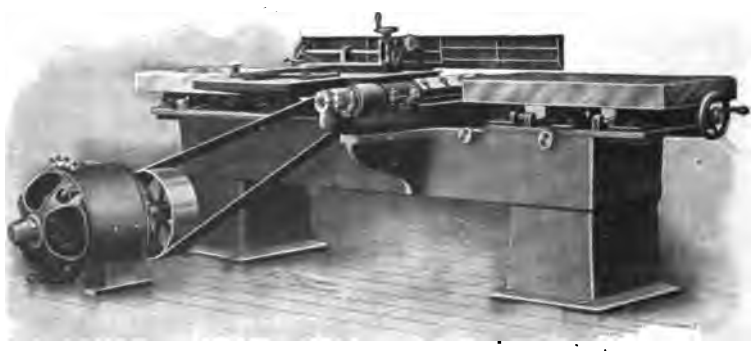
Fig. 57.

Fig. 58.

finish and draft on patterns, it being understood that the former must always be present where the surface is to be machined and the latter where a vertical surface is to be drawn out of the sand.

In Fig. 57 let A B be the parting line between the cope and the drag. The pattern is first placed face down on the moulding board, the drag is placed around it and the sand rammed home. The drag with the pattern is then turned over, the cope put on and the sand rammed. Then on lifting off the cope, the sand lying in the curve C E D is lifted with it, allowing the pattern to be removed from the sand of the drag without disturbing anything.

One more example of one-piece patterns will be given. Fig. 58 is a small handwheel that is usually made solid. It will be seen, however, that if the pattern were to be rammed in the sand with the parting line between cope and drag on the line C D it would be impossible to remove it. It may, however, be rammed in this way and then the sand cut and removed down to the center line A B, after which the cope may be put on and rammed. This makes the parting line between the two run on C *c a d e* D, so that the pattern is readily drawn from the sand of the drag after the cope has been removed.



Representative Standard Hand Planers Made by American Machinery Company.

The pattern maker should therefore be familiar with foundry work in order to obtain the best results.

Cores. Cores are used for forming the hollow spaces inside of castings and must be provided for by the pattern maker. The simplest and at the same time, the most common core is a straight cylinder. If by reason of its small size it is desirable to core the hollow through Fig. 59, the pattern would be made solid as shown, and two core prints *a* and *b* be placed upon either end. These prints should have the shape of a truncated cone whose larger diameter is $\frac{1}{4}$ inch smaller than the finished hole through the gland. The height of the print would be dependent upon the diameter and length of the core, and ranges from a projection of 1 inch to 6 inches. In Fig. 59 the print *a* is loosely attached to the pattern for reasons that will be explained later.

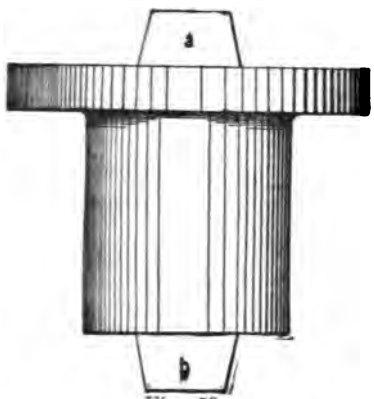


Fig. 59.

Cores are used when the shape of the casting is to be such that the pattern cannot be made to leave its own core and where the green sand core, if left, would probably be washed away by the flowing molten metal.

Core Boxes. Round cores are usually made in two-part boxes cut on a plane through the axis of the cylinder and for small cores held together by dowel pins. For the larger sizes of 3 inches or more in diameter single half boxes as in Fig. 60 are used. The core sand is packed in the box, turned out on the table and two pieces pasted together making a round core of the diameter of the box.

It is customary in most foundries to have a complete set of these coreboxes ranging in size from 1 inch in diameter up to the largest size for which the ordinary work of the establishment may call. The boxes are made long enough so that the cores can be cut to any desired length.

In the making of such a corebox, the box in which the groove is cut is first gotten out and a semi-circle scribed on each end with

lines connecting the extremities of the same, drawn across the face of the block. The groove is first roughly cut out with the gouge and then finished with the corebox plane, or with the gouge, using the square as shown in Fig. 61 to test the accuracy of the work. The curve is then sandpapered, varnished and the ends closed with the pieces *a* and *b* as shown in Fig. 62.

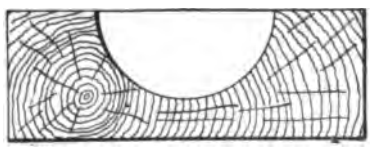


Fig. 60.

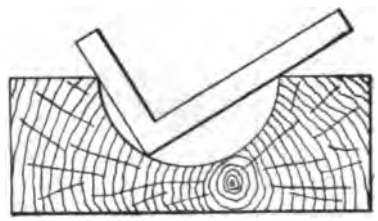


Fig. 61.

For cores of large diameter the boxes are built up as shown in Fig. 63. The corners of the projecting pieces are then removed with the gouge and the box finished to the guide lines with the corebox plane as before.

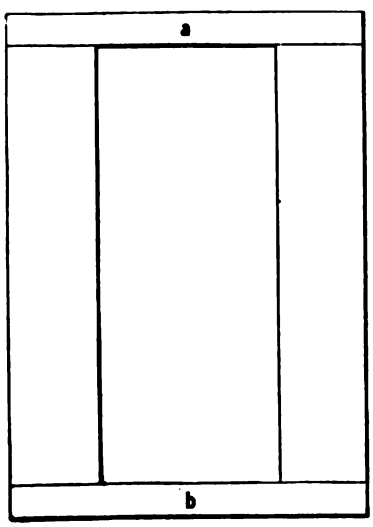


Fig. 62.

If, however, the box is so large that the diameter is greater than the side of the corebox plane as in Fig. 64 so that a bearing cannot be obtained upon both sides of the groove at the same time, it will be necessary to work as close as possible to the guide lines with a gouge using the square for testing the work as in Fig. 61 and then finish with a round soled plane, Fig. 16, whose radius is a little less than that of the groove to be cut.

Sometimes, as already stated, two halves of a corebox are made and the sand rammed into the hole thus formed from the end. In such cases the two parts are brought into an accurate alignment by means of dowel pins. In one half there is a

dowel pin that is adjusted to fit accurately in a corresponding hole in the other half as shown in Fig. 65. There should never be less than two of these pins and the number should be increased with the size of the corebox or pattern, since patterns are held together in the same way. These pins are usually of hard wood about $\frac{3}{8}$ inch in diameter and are bought in lengths from which the individual dowels are cut. They should be driven firmly home, glued into one piece and have an accurate fit in the other half. The point should be beveled so as to enter the hole readily and the whole pin should be from $\frac{1}{2}$ inch to $\frac{5}{8}$ inch in length.

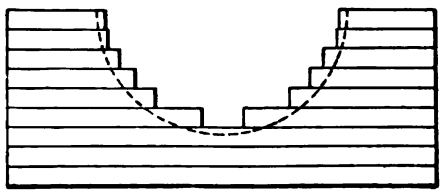


Fig. 63.

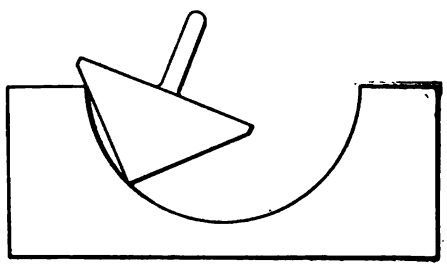


Fig. 64.

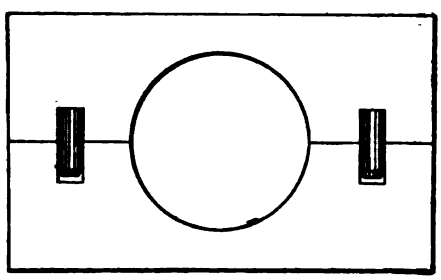


Fig. 65.

In locating dowel pins it is, of course, very necessary that the pin and hole should be accurately placed. This can be done by measurements but the simplest way is to lay an ordinary pin on the face of one half with the head where it is desired to locate the center of the dowel. Then by adjusting the parts and pressing them together the pin will indent the wood on each and thus mark the point at which the holes are to be bored.

Two Part Patterns. The greater portion of cast iron and brass work is so designed that it is necessary to make the patterns in two pieces. Small patterns may be made of a single piece of wood though warping is likely to occur after they have been used for a time and have been subjected to the alternate moisture of the moulding sand and the extreme dryness of the pattern loft. Large and expensive patterns are, therefore, invariably built

up of thin pieces that are glued and nailed together properly.

An example of a simple two-part pattern is given in Fig. 66 which represents a section of cast iron pipe with flanges at each end. The pattern may be solid, or, if it is of large size, the

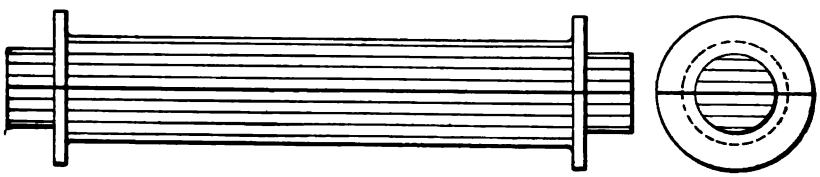


Fig. 66.

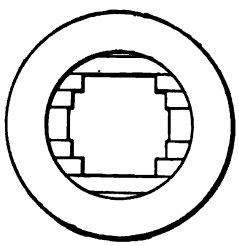


Fig. 67.

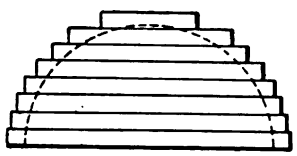


Fig. 68.

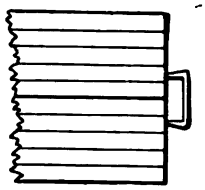


Fig. 69.

building up may be so arranged that the interior is hollow as shown in the section given in Fig. 67. In making such a pattern the pieces used for building up are cut approximately to size, glued and nailed together. Each half is made separately until two pieces, each of a section like that shown in Fig. 68 are obtained. The dowel pins are then driven firmly into one, the holes adjusted in the other and the two parts held together by staple dogs driven in at the ends as in Fig. 69. The head and tail-stock centers of the lathe are then set on the parting line and the whole turned to a cylindrical shape as though it were a single solid block. After turning, the flanges are cut out and nailed or glued in position. The projections beyond the flanges are the core prints upon which the core, forming the exterior of the pipe, rests. These prints are of the same diameter as the core and the inside diameter of the pipe. Hence, when the metal is poured, the casting has the form of a pipe with flanged ends as desired.

The method of moulding such a pipe will be treated in connection with instruction on foundry work. It will, of course, be

impossible in any work on pattern making to give detailed instructions for the making of every pattern that may be called for; but the instructions given for the making of a few of the more common articles will serve as a guide.

Face Plate. It is sometimes advisable to use cores even if it is quite possible to construct the pattern so that it would core its own holes. This is the case where it is desired that the faces of the casting should be smooth and as true as possible without expensive machine work. Such a case is found in the face plate of an engine lathe, a drawing of the finished product being shown in Fig. 70.

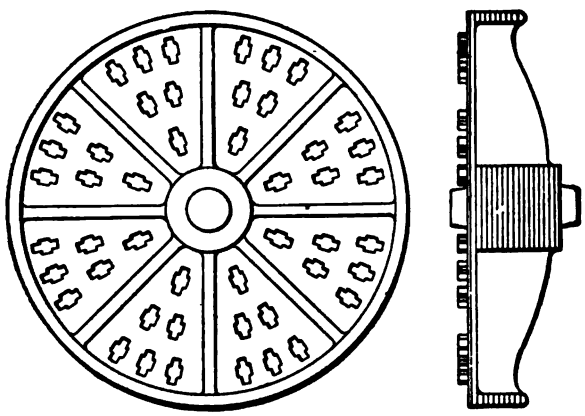


Fig. 70.

It will be readily seen that this casting could be put in the sand, rammed home, and withdrawn leaving the sand standing where the holes are located.

The trouble that would arise from this method would lie in the fact that when the metal is poured and allowed to flow about the fragile projections that are left to form the holes the sand would be washed away, so that the holes in the casting would be irregular and much smaller than those in the pattern. The quality of the iron is injured by the sand which is caught on the upper surface.

For these reasons the holes should be cored, as the core sand is firmer and better able to resist the washing action of the flowing metal.

The pattern for such a face plate should, therefore, be made as follows: First it is to be noted that the metal must be thicker than the finished piece on the surfaces. Having thus determined the thickness of the pattern on the face, the disc should be built up of from four to sixteen segments according to the size of the plate. If the diameter lies between 30 and 42 inches, sixteen sectors should be cut out each filling an arc of 45° so that when eight are placed edge to edge they will complete the circle. The thickness should be a little more than one-half the completed thickness of the pattern disc and they should be laid up so as to form two layers, breaking joints with each other.

When this disc is formed the hub should be glued and screwed in position, this also being built up of pieces glued together. The rim is then built upon the disc. This is done by cutting segments of $\frac{1}{2}$ inch or $\frac{3}{4}$ inch stock and gluing them in a circle of the proper diameter. In building up to the proper height care must be taken that no joints of two adjoining layers coincide but that all joints are broken.

The pattern now consists of the disc with the rim and hub in position but larger than they should be. It is, therefore, placed in the lathe and carefully turned over its whole surface, each part and thickness being brought to the shape and dimensions of the completed pattern. It will be found convenient, however, to cut all angles square, leaving the fillets to be put in later.

The next step is to put in the ribs. It will be unnecessary to form these out of built-up material, for each may be cut from a single piece.

They should be carefully fitted to form a close joint with the rim, the disc, and the hub, before they are glued in position. When this is done, all the angles formed by the rim, spokes, and hub with each other should be carefully filleted. That is to say, a quarter curve should be placed in these corners so that there may be no sudden change in direction of the surface of the casting which may cause weakness.

These fillets are made in various ways; the cheapest and most unreliable is putty which depends upon its own adhesiveness and a film of varnish to keep it in position. This is sometimes employed but is not to be recommended. Beeswax used in the

same manner is better but is not good. Next comes a wooden fillet cut as in Fig. 71, nailed and glued in position. This forms a substantial fillet, and if properly put in, will last as long as the pattern. Metal fillets of the same shape are also sold and serve the purpose equally as well if not better than wood. The radius of curvatures of these fillets varies from $\frac{1}{4}$ inch up, dependent upon the size and weight of the casting.

Fig. 71.

After the fillets are in position it remains to provide for the coring of the holes. This is done by first laying out upon one face of the pattern the location and size of the holes. It is upon the points thus located that the core prints are placed. Before this is done it must be decided which side of the casting is to be made uppermost.

Where a large, flat surface is to be given a finish it is desirable that the metal should be as clean and free from sand and blowholes as possible. As the iron has a greater specific gravity than the sand of the mould, all particles of sand that may be washed away and all gases generated, rise to the surface of the molten metal. Those imprisoned by the cooling of the latter form the dirt and blowholes that disfigure the completed casting. In such a casting as the faceplate under consideration it is desirable, then, that the face should be upon the lower side when the metal is poured. For the sake of convenience in setting the cores, the prints are, therefore, put upon the face and make their impress in the sand of the drag. They should be glued and nailed in position after the pattern itself has been sandpapered. The core prints for the hole through the center are also put on in the same way.

Gluing. In describing the method followed in the construction of the faceplate pattern, it was directed that certain parts should be glued together.

First get a good quality of glue, then keep it cool, in a clean box and protected from the dust. The glue-pot in which it is to be prepared should always be double; that is, there should be an outer pot partly filled with water into which the smaller inner pot used for the direct preparation of the glue should be placed.

This is to avoid burning, since if the glue is overheated its adhesive qualities will be greatly impaired. This cannot happen if set in a pot of boiling water whereas it can hardly fail to occur if the heat of the fire is applied direct. The most convenient form of pot is one where the water in the outer pot is heated by steam.

When the glue is to be used, it should first be washed in cold water and then broken up with a hammer. After being placed in the inner pot it should be well covered with clean water. As it heats stir it from time to time with a stick and throw away any scum that may rise to the surface.

Glue joints may be made with the truing plane, a larger one called a jointer, or, if the piece comes within the capacity of the machine, on the universal trimmer. The joint should be very carefully made so that the two pieces of wood are in contact over their whole surfaces. When these have been properly prepared the glue is spread over them and they are pressed tightly together. Where the surfaces are large or long it is well to move them to and fro over each other before the glue sets in order to work out all the air and superfluous glue. The pieces should then be held together by clamps or weights until the glue has thoroughly set.

Sometimes a difficulty will arise in the case of large surfaces of thin material. When the glue is applied it moistens and therefore has a tendency to expand the surface upon which it is placed, causing the edges to curl up and pull away from the opposing piece which has a tendency to move in the opposite direction. This may be diminished by moistening the back of these thin pieces with water from the outer kettle.

When it is desired to have the glue set more quickly than it would in its natural condition, the addition of whiting will accomplish it. The greater the quantity that is added the more rapid will be the setting but it must be borne in mind that this forcing of the setting weakens the glue.

In cold weather the precaution must be taken to heat the pieces before applying the glue, else the latter may be prematurely chilled and fail to set.

The time required for a well-made joint to set is from one and a half to three hours, dependent upon the quality of the wood and the thickness of the glue.

Where the pieces are held by glue alone and work is to be done upon them in the lathe or at the bench, it is well, if possible, to allow the glue a whole night to set before proceeding with such work.

Engine Crank. A more simple pattern than the one last described is to be found in the engine crank illustrated by Fig. 72. As before, if the face is to be finished it should be cast with that side down. The construction of the pattern is very simple and consists of cutting out the several pieces that go to form the body and boss of the crank, then nailing and gluing them together to form the pattern. After this has been done and the pattern has been carefully sandpapered, the cores are attached and set on with single dowel pins located at their centers.

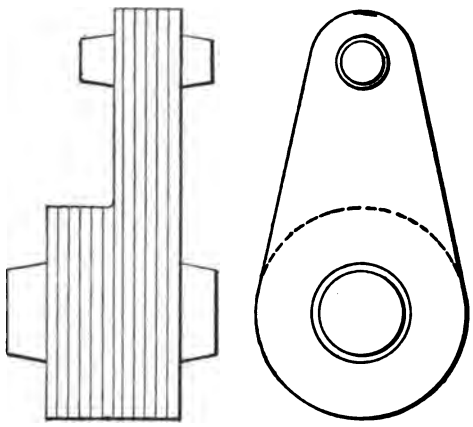


Fig. 72.

Tee Pipe connections are common features of pattern work in nearly all shops. The size of the connection determines whether the body of the pattern is to be of a solid block of wood or is to be built up. In the construction of the T shown in Fig. 73 either method may be followed. The body and branch are prepared and turned separately and the flanges put on in exactly the same manner as that given in the description of the making of flanged pipe pattern Fig. 66. The pattern must be made in two parts. The union of the branch with the main body may be made in one of two ways. It may be cut away on a circle as shown in Fig. 74 or a V-shaped slot may be cut in the body and the end of the branch fitted into it. The latter, if well made, is the better way as a more substantial job can be done. Either method leaves an angle on the line of unison *a b c* which should be eased off by the use of a fillet.

The core prints on the T are square at the ends because they

draw out sideways from the sand and the flasks are apart when the core is placed in its position.

The core box is made like those of circular cores already described and the two parts of stem and branch are easily fastened together. The most satisfactory way will be to make the box for the stem and then cut the side inlet to its edge and finally fasten the branch on the side with glue and nails, giving it sufficient length to reach to the end of its own particular core print.

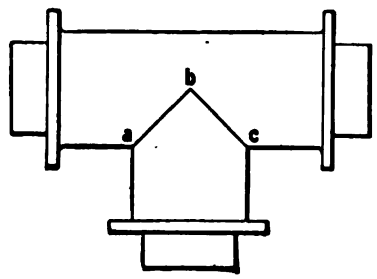


Fig. 73.

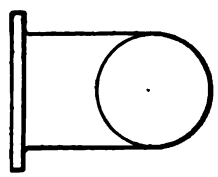


Fig. 74.

The patterns for elbows, bends, and angle tees may be made in exactly the same way.

Pulleys. Almost every patternshop is called upon, from time to time, to make patterns for pulleys. There are two ways in which this can be done; one is to build up a rim of wood and put in the hub and spokes thus making a complete pattern; the other is to make a skeleton pattern consisting of the hub and spokes and an independent iron rim. This rim may be used for obtaining any breadth of face that may be desired. The former method is rarely employed as it is expensive and with it any variation in the width of the rim of the casting is made with difficulty.

Where the iron rim is to be made no great care is necessary in the building up of the original wooden pattern. It must be remembered that before the final casting is obtained, two shrinkages will take place; first, the shrinkage of the original casting from which the iron ring is turned and then the shrinkage of the casting made from this pattern. In addition to this, there must be the allowance for turning the ring inside and out and the turning of the outside pulley rim. Suppose the pattern is to be made for a pulley 2 feet in diameter. The usual allowance for a single

shrinkage is made by the shrinkage rule, to which must be added as much more. Thus in the case of the above pulley, the diameter of the wooden pattern becomes

$$24\tfrac{1}{4} + \tfrac{1}{4} = 24\tfrac{1}{2} \text{ inches.}$$

As $\frac{1}{4}$ inch must be allowed for the outside finish of the iron ring and as much more for that of the rim of the pulley, the outside diameter of the original wooden pattern is 25 inches as measured with a common rule or $24\frac{3}{4}$ inches as measured with the shrinkage rule. If the final thickness of the rim is to be $\frac{3}{8}$ inch, this, with the allowance of $\frac{1}{8}$ inch for the turning of the inside of the iron ring makes the inside diameter of the wooden ring $24\frac{1}{4} - 2\ (\frac{3}{8} + \frac{1}{8}) = 23\frac{1}{4}$ inches as measured by the common rule or 23 inches (about) as measured by the shrinkage rule. The original pattern should then be built up of segments nailed together until a width of about $4\frac{1}{2}$ or 5 inches is obtained. It is then put in a lathe and turned to the proper diameters and *without any draft*. This pattern is then sent to the foundry and a casting made at least $6\frac{1}{2}$ inches wide. This can be done in the foundry by first ramming the sand about the pattern and partly drawing the pattern and then ramming again to the new level.

The casting thus obtained is then turned to the dimensions called for by an ordinary pattern; that is to say, the shrinkage rule measurements would leave it $23\frac{1}{4}$ inches diameter on the inside and $24\frac{1}{4}$ inches on the outside, permitting a final finishing of the outside of the rim of the pulley to a diameter of 24 inches. When this is done two $\frac{3}{8}$ inch holes should be drilled near one edge of the rim and diametrically opposite each other, into which hooks may be inserted for drawing the pattern. This ring should also be turned straight and without any draft.

The spokes are usually made with a wooden pattern, which has a dowel pin hole on each side at the center for attaching the hubs that are loose, the object being to be able to change their length and diameter to suit the width of the rim and the diameter of the shaft upon which the pulley is likely to be placed.

The spoke is usually curved except on very small pulleys. The reason is that there is often a greater thickness of metal in the hub and spoke than in the rim, so that after casting, the former

cools more slowly than the latter, with the result that, if the spokes are straight they will pull squarely against the rim and set up internal stresses which are apt to crack the metal. With the curved spoke, on the other hand, the metal yields like a spring and does not break.

In making the wooden pattern, Fig. 75, for the spokes, the first matter to be determined is the largest djameter of shaft upon

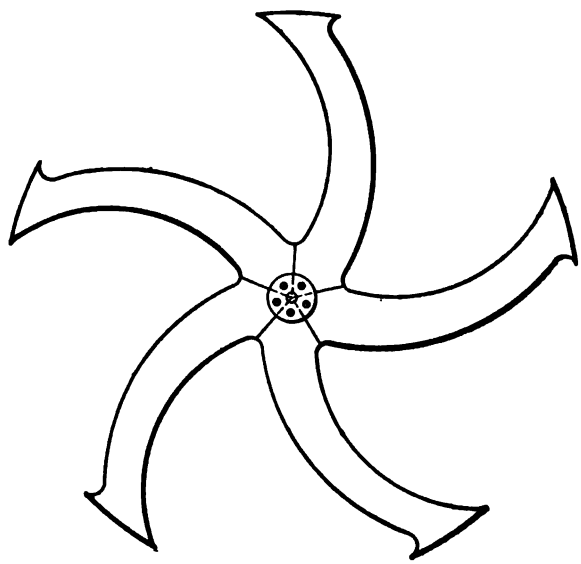


Fig. 75.

which it is to be run. An ordinary rule is to make the outside diameter of the hub twice the diameter of the shaft, and the curve of the spokes should sweep down and merge into the hub. Then we should consider the number of spokes, which should vary with the diameter of the pulley; but it should be remembered that an odd number is better than an even, because then no spoke in shrinking, is pulling directly against any other. As for the dimensions of the arms, a trained eye is as good a guide as any

rule. But for the beginner the following formula is safe to follow:

$$b = \sqrt[3]{\frac{d \times w}{n \times 8}}$$

in which

b = the breadth of the arm at the outer end,
d = the outside diameter of the pulley,
w = the width of the rim,
n = the number of spokes,

all dimensions being taken in inches.

Thus for a pulley 24 inches in diameter with a rim 6 inches wide and fitted with 5 spokes, the formula becomes:

$$b = \sqrt[3]{\frac{24 \times 6}{5 \times 8}} = \sqrt[3]{3.6}$$

Hence, $b = 1.53$ inches or $1\frac{1}{2}$ inches.

The width of the spoke should be one-third greater at the hub than at the rim. The thickness at the hub and rim should be one-half the width, and the section should be elliptical. The spoke just calculated then becomes,

$1\frac{1}{2}$ inches wide at rim,
$\frac{3}{4}$ inch thick at rim,
2 inches wide at hub,
1 inch thick at hub.

The curve of the pulley arm should be so designed that there is an ample curvature to permit the yielding already referred to, and yet be straight enough to have the requisite stiffness. The usual method employed in designing these spokes is to roughly outline the arm with a pencil to a graceful shape and then adapt radii to it so that it may be drawn with instruments.

The common method of constructing the pattern is to make each spoke of a separate piece of wood with the grain running in the general direction of the spoke and fasten them together at the center with glue and a flat plate or ring as in Fig. 75, which can also be used as a rapping plate. This need only be split or made in two pieces in the case of very large and heavy wheels. For all ordinary work it can be made in one piece and moulded as directed in connection with the handwheel on page 32.

The hubs are usually loose and are held central by a single dowel pin. Their diameters are adapted to the size of the shaft upon which the pulley is to run, and the length is proportioned to the width of the rim as well as its diameter. The length of the boss should be about two-thirds the width of the rim except in the cases of tight-and-loose pulleys where the hub should be a trifle longer than the width of the rim. It may then project about $\frac{1}{8}$ inch on the sides in contact and $\frac{1}{4}$ inch on the outside.

Rapping Plates. In the description of the making of the pulley pattern the ring serving as a binder for the hub is spoken of as a rapping plate. When a pattern is imbedded in the sand, the latter is closely compressed all about it and slightly adheres. The moulder is, therefore, in the habit of rapping the pattern gently in order to loosen it in the sand before attempting to draw it. If the pattern is not provided with a metal plate, the moulder will drive the sharp point of a lifter into the wood and strike it alternately on opposite sides and at the same time use it to lift the pattern from the sand. This mars the pattern and will in time ruin it. The rapping plate, Fig. 76, is a piece of thin metal $\frac{1}{8}$ to $\frac{3}{16}$ inch thick, inserted so that it is flush with the parting face of the pattern and is held by wood screws with countersunk heads. These plates are drilled and tapped for a $\frac{3}{8}$ inch screw and should be the same for all the patterns in the foundry so that one set of rods can be used interchangeably. The method of using is to screw the rod into the plate and rap it gently to and fro until the pattern has been loosened, when it may be lifted. For small patterns one rapping plate will be sufficient and this should be so placed that the hole for the lifting rod comes directly over the center of gravity of the piece. This will prevent tilting of the pattern as it is lifted from the sand. For medium sized patterns, two rapping plates should be provided, so that the pattern can be raised from two opposite sides. For still larger patterns three or four rapping plates are used; the object being to give such perfect control when drawing that there can be no tearing away of the sand.

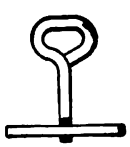


Fig. 76.

Metal Patterns. In the pattern for the pulley a portion of

it is described as made of iron. Metal patterns are extensively used where either one of two conditions prevail: first, where the character of the work is so light and delicate that a wooden pattern would not be able to hold together, such as in ornamental castings; and second, where such a large number of castings are to be made that the wooden pattern would not last long enough to complete the job. This latter condition prevails where brake shoes are made by the thousand from a single pattern.

The metal pattern may be made of iron or brass. The work of forming it should be very carefully performed and it should be turned, planed, and filed so that it is perfectly smooth. If brass is used, it is customary to give it a light coating of shellac varnish, but it is not absolutely necessary. Where iron is used some preservative must be put upon the surfaces to protect them from rust. The best method is to warm the metal and rub it with a rag dipped in melted beeswax. This excludes the air and leaves a smooth surface so that it is easily drawn out of the sand. This, however, is not a very durable protection; the more common method is to use a shellac varnish. In order that the varnish may adhere, the metal should first be wet with a solution of sal ammoniac and allowed to dry; it is then sandpapered and varnished.

Varnishing. For two reasons all patterns should be varnished before being sent to the foundry. First, the varnish forms a protective coating to the wood or metal against the moisture in the sand of the mould; second, it gives a smooth glossy surface to the pattern so that it is easily withdrawn from the mould. The varnish universally used by pattern makers is shellac. It should always be prepared in the shop where it is used. It is made by dissolving shellac in alcohol in the proportion of two pounds to the gallon. The actual dissolving may, however, be done by putting the shellac in the bottom of an earthenware vessel and pouring in enough of the liquid to cover it. This will make a varnish too thick for use but it can be thinned to the proper consistency by the addition of more alcohol. The varnish should always be kept in an earthenware vessel as a metallic one is apt to discolor it. The varnish pot should be fitted with a close cover with a hole for the handle of the brush which should be suspended in the pot.

It is customary to apply the varnish clear which will thus

give a yellow color. For the core prints a small quantity of ivory lampblack is added to the varnish before applying. The prints being black enables the moulder to decide the use for which they are intended.

Sometimes French vermillion is put in the varnish for the body of the pattern, black being put upon the coreprints. Any coloring matter may be used, but to obtain an even color the coat should be light. Where heavy pigments are mixed with the varnish they quickly sink to the bottom and frequent stirring is necessary.

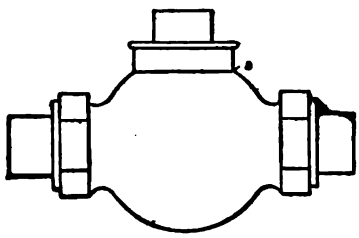


Fig. 77.

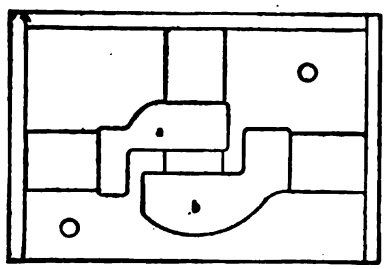
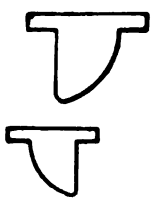


Fig. 78



Figs. 80 and 81.

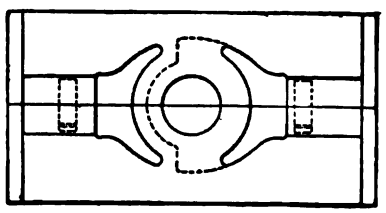


Fig. 79.

Valves. The outside contour of castings may be quite smooth and even, while the cores, by which the interior is formed, are very irregular. Such is the case with an ordinary globe valve casing whose external appearance is shown in Fig. 77. A side elevation of one-half of the corebox, Fig. 78, however shows that the interior is of a very irregular form. The external appearance of the pattern should be the same as the body of the valve shown in Fig. 77. It should be built up of thin pieces glued together, except for valves intended for $\frac{3}{4}$ inch pipe or less, when, the halves may be each of a single piece of wood, including the coreprints.

It is the core box that will give the greatest amount of trouble

Standard Wood Trimmers Made by American Machinery Company.

The elevation of the face and horizontal section of the core box, Fig. 79, shows that the interior is irregular in form and that the halves of the core must be made in separate boxes and pasted together. This box must be cut out entirely by hand tools as the irregularity of the interior makes it impossible to use any machine.

The method of procedure is to lay out upon the face of each half of the core box, the outline corresponding to that of the core prints. At the ends semi-circles should be described to outline the edges of the print. For cutting out the interior cores *a* and *b*, Fig. 78, it is well to make wooden templates so that the core may be easily cut to the required depth. If made too deep the metal of the seat would be thinner than it should be; if not deep enough, the passages would be contracted and the weight of the valve increased. These templates should have a form resembling the contour of a vertical section of the passages for which they are intended. Thus a template for the narrow neck of *a* would be shaped as in Fig. 80, and for the space beneath the valve seat in *b* as shown in Fig. 81.

After the core boxes have been carefully cut out with the hand tools, they should be scraped, sandpapered, and shellaced.

The pattern itself can be turned in the lathe, the two parts being held together as by the method described in connection with the pipe pattern, Fig. 69. After the turning has been done the hexagonal ends should be cut out of the same material. This may be done if the rough material at these points is left untouched by the turning gouge and chisels. Turning leaves the body in the shape of a globe. After the hexagonal ends have been cut, the neck for the stuffing box and the stem is to be turned and glued in position.

As the line of intersection of the cylindrical neck and the spherical case is a circle, it is simply necessary to flatten the top of the case and lay the neck upon it. The connection between the two at *a*, will then be angular and must be eased off by the use of a fillet. The coreprint of the neck is turned solid with the neck itself which must, of course, be made in halves like the body of the valve.

Where a piece is laid upon a pattern in this way it is well to

strengthen the glued joint by the use of a thin plate of metal firmly screwed to the two parts thus united.

Pillow Blocks. In the ordinary pillow block, Fig. 82, we revert, once more, to the single-piece pattern. These patterns are exceedingly simple to construct. They are in such constant

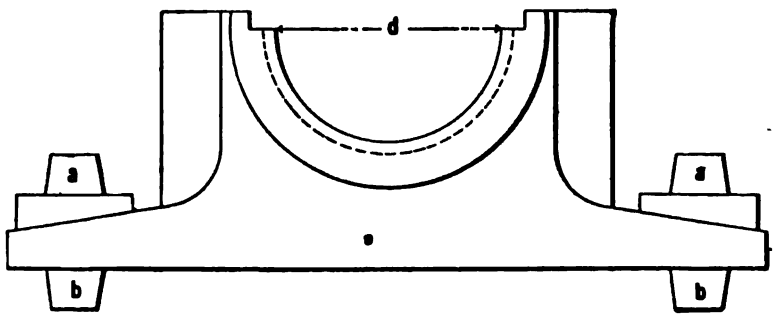


Fig. 82.

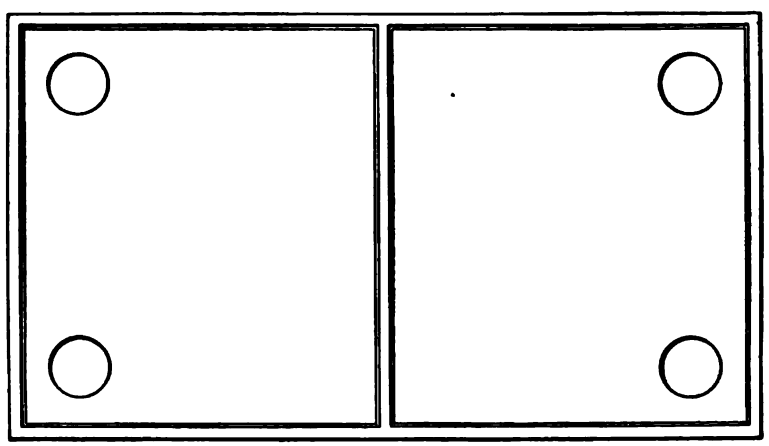


Fig. 83.

demand that every pattern shop is frequently called upon to make the different sizes.

Where the width of the block or the length of the bearing is not more than 12 inches, the base, B, may be made of one solid piece of board; one face should be left smooth if it is intended to finish the bottom in a machine. If the bottom is to be chipped to

fit into its position it should be ribbed as shown in Fig. 83. The height of the ribs should be about $\frac{1}{8}$ inch.

Upon the upper face should be glued and nailed the body of the block. It should be built up and the shaft core should be cut out with the core-box plane as already described for the core box. It will facilitate this work if the grain of the wood is laid to run across the block.

As blocks of this kind are usually babbitted upon the rough casting, provision must be made to hold the same. For this purpose a narrow rib is made around the inside of the box at the ends as shown by the dotted lines of Fig. 82. The top of this rib should be $\frac{1}{4}$ inch wide, the bottom $\frac{3}{8}$ inch and its height should be dependent upon the nominal size of the box. For large boxes of

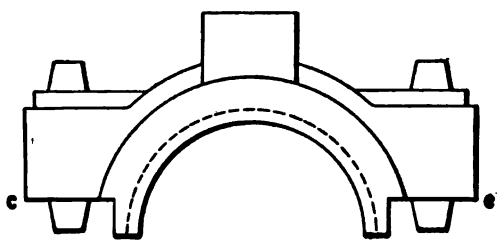


Fig. 84.

eight inches or more diameter they may be $\frac{3}{8}$ inch high, but for ordinary boxes $\frac{1}{4}$ inch is enough. The top of the rib should be $\frac{1}{8}$ inch from the shaft. That is to say, the diameter, *d*, should be $\frac{1}{4}$ inch greater than that of the shaft for which the box is intended.

After the box has been formed the coreprints, *a a*, are to be fastened on, and the prints, *b b*, put on loosely so that they may be imbedded in the sand of the cope. The cores which are set in these prints form the bolt holes by which the block is held to its foundation.

In moulding, pillow blocks are cast bottom up, thus insuring sound metal for the completed casting.

The cap for this block, Fig. 84, is made in one piece, it being quite possible to cut away the sand so that the parting between the cope and the drag will come along the line *c e* as described in connection with the handwheel, Fig. 58.

This pattern is also cast bottom up, insuring sound metal on the top that is exposed to view.

Bearings. Where babbited boxes are not used, it is customary to insert a brass or soft metal bearing for which a special pattern is to be made. The details of such a pattern do not differ in any way from those intended for use in iron castings, but a slightly different shrinkage rule must be used.

Columns differ somewhat from pipes. Instead of a smooth outer surface they are commonly fluted or fitted with ornamentations of some sort. It will be seen by reference to a half section of a fluted column, Fig. 85, that if the pattern were to be made like the completed casting it would be impossible to get it out of the mould without tearing away the sand where the pattern is under cut as at *a' a'*. Loose pieces are therefore used.

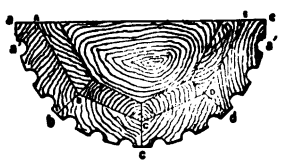


Fig. 85.

The body of the pattern is made octagonal as shown by the line A B C D E. The loose pieces forming the flutes are held to the main body by pins that stand at right angles to the line A E. After the sand has been rammed, the body included in the lines A B C D E is lifted out leaving the parts A *a b* B, B *b c* C, etc., imbedded in the sand. Then one after another these are lifted out.

These fluted sections should never be so few in number that they cannot be lifted out without tearing the sand. In small work six sections can be used; eight is better and in some twelve are needed.

Other forms of ornamentation are put upon columns in a similar manner. Leaves or flowers are held by pins or in grooves in such a way that the main body of the pattern can be lifted out without disturbing them, and they are then withdrawn from the sand through the cavity left by the main pattern.

Cores for Columns. Cores for columns may be made in core boxes as in the case of those for pipe, but where the core is long and straight no core box is needed. The core is usually built of loam about an iron pipe as will be explained in the section on Foundry Work.

Where the core is to follow the lines of the ornamental mouldings on the outside of the column, it may be provided with a special core box or better with a sweep as shown in Fig. 86. This sweep is used to shape the loam core that is to be built up on an iron pipe.

Fig. 86 is the outline of the template that is to be used in sweeping the core for the interior of the columns shown in Fig. 87.

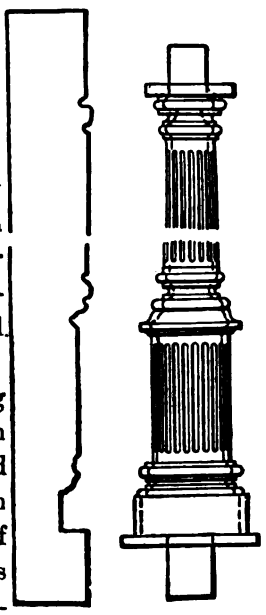


Fig. 86. Fig. 87.

Thin Patterns. Where the casting to be made is thin extra precaution must be taken. The unequal pressure caused by ramming the sand will distort a thin pattern so that the casting will not have the proper outlines. This may be prevented by supporting the pattern while the sand of the nowel is being rammed about it.

Fig. 88 represents a section of a railing cap. If the pattern B were to be set with its edges *a a* resting upon the moulding board and the sand of the drag rammed down upon its upper face, it would be sprung out of shape. To avoid this the follow board A is made to exactly fit the under side of the pattern. Then when the sand is rammed, the whole pattern is supported and there will be no distortion. When the cope is rammed the follow board is removed and the sand of the drag supports the pattern.

Fig. 88.

Thin patterns and all that are likely to suffer from distortion due to sand pressures should be provided with accurately fitting follow boards, and where the number of castings is large, the patterns themselves should be of metal.

Engine Cylinder. Engine cylinders may be made in either of two ways. There may be a regular pattern or a loam mould may be constructed. The latter method will be fully described in the section on Foundry Work. It may be stated in general that loam moulding is used for cylinders of large dimensions and pat-

terns for those of small. The dividing line varies in different foundries and ranges from 24 inches to 30 inches of diameter.

In order that a pattern maker may construct a cylinder pattern, he should be provided with drawings showing in detail a

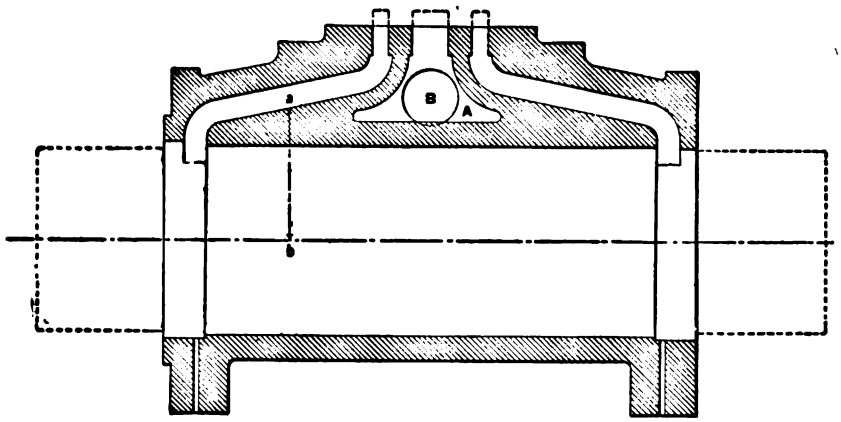


Fig. 89.

longitudinal section, a cross-section, and a plan of the completed cylinder as in Figs. 89, 90, and 91. The longitudinal section should be redrawn to full size on a chalked board as described on page 3.

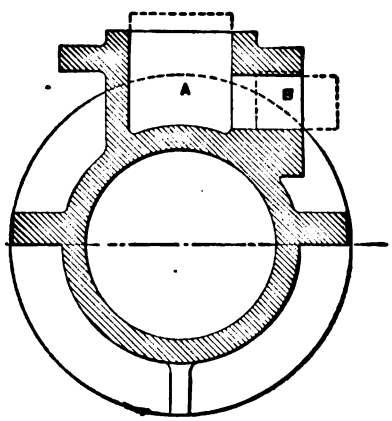


Fig. 90.

In order that the weight of the pattern may be as small as possible the cylindrical portion should be built up and hollow. The dotted lines shown in Figs. 89 and 90 indicate the core prints on the pattern. First as to the two latter, it will be seen that they are smaller in diameter than the finished bore. This is to allow for finishing as already explained.

The barrel of the cylinder is to be constructed first. This should be made up of strips one inch thick. First cut four pieces as A A (Fig. 92) carefully jointed in pairs along the line *a a*.

These are to form the ends of the barrel. They should be fastened by dowels. The number of faces of the polygon should depend upon the size of the cylinder.

Next cut and fit on each face of the polygon the strips *b b*, glueing and nailing them in position. Thus a hollow polygonal

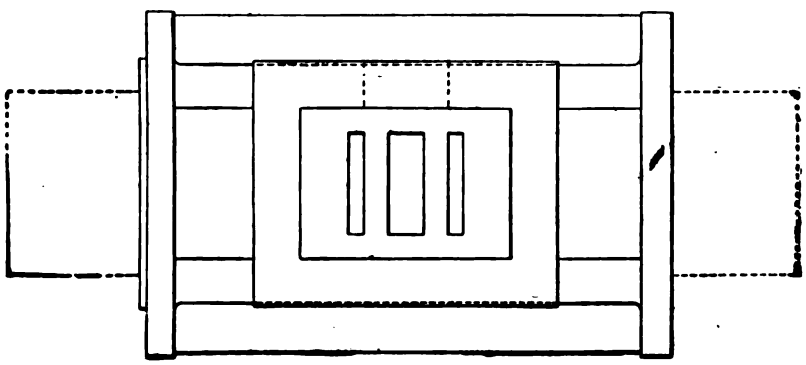


Fig. 91.

prism will be formed, which may be centered on its parting line *a a* and turned to a cylindrical form.

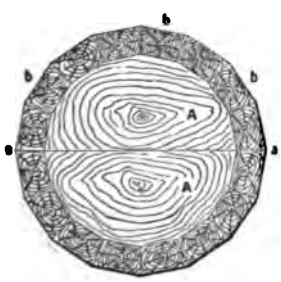


Fig. 92.

When this has been done the casing for the passage of the ports and the plugs for supporting the cylinder are built upon the curved faces of the cylinder as turned and the steam-chest seat laid on.

The core prints for the ports and exhaust pipe are then glued on and finally the core prints for the body fastened. These latter may, however, be built on the polygonal ends at the same time as the body. Or, they may be made in the same way and screwed to the ends after the completion of the pattern. The latter method usually makes the lightest job.

The core boxes of a cylinder pattern are usually somewhat intricate. The core for the main body is simply cylindrical like that used for pipes except that in two places a piece is set upon the inner surface of the box. These form indentations or prints in the core itself to receive the cores forming the ports. If desirable the core may be made of loam.

The cores of the ports must have a curvature on their cross-section at the points *d d*, Figs. 93 and 95, to conform to the curve of the cylinder's shell. In order that the shape of the port shall correspond with that called for by the drawing, first make a template to exactly correspond with the full-size drawing of the port as given in Fig. 89 and duplicated on the chalk board.

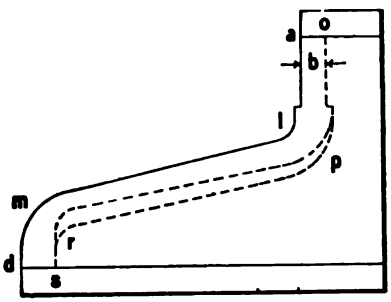


Fig. 93.

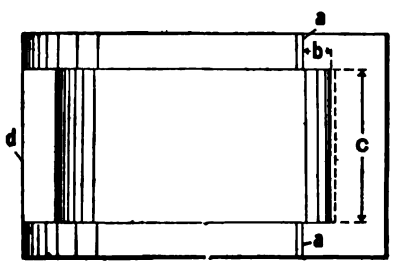


Fig. 95.

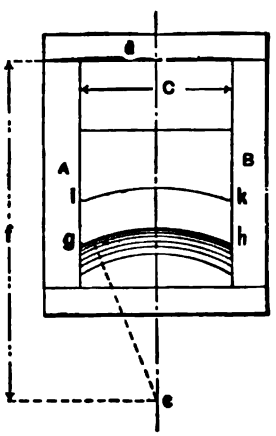


Fig 94.

Build up a block of which Figs. 93, 94, and 95 are general outlines. In these three figures the same letters refer to the same parts. Square the edge *a a* and from it lay off the width and length of the port according to the dimensions *b* and C respectively. On the face *d* describe the arc of a circle *g h* from the point *e*, letting the perpendicular distance *f* from *a* to *e* be equal to the distance from the valve face to the center of the cylinder plus the height of the core-print on Fig. 89.

Then with the template of the port for a guide, cut out the material of the block so that it fits accurately along the center line

from the edge *a* to the curve *g h*. Take the distance *a b* on Fig. 89 for a radius and strike an arc whose cord is equal to the length of the port *C* (Fig. 94). With the concave surface of this arc as a template cut away the material of the block to form the bottom of the core as shown by the line *i k* of Fig. 94. The edges, *a l m d* of Fig. 93, bounding the core ends *i k* should rise the width of the port, away from the bounding line at the bottom as shown by the dotted line *o p r s*. The cover to this core should fit the faces A and B of Fig. 94 and have the same curvature over the body of the core as *i k*. The sides of the core where they intersect the valve-seat at *a o* and along the shell of the cylinder at *d s* are flat. These two parts exceed the length of the cored passages by the length of the prints. One core box will answer for both steam ports.

The core box for the exhaust passage is a simpler box to make. It is made in halves the face view of each being the same as that of the exhaust passage A, as shown in Fig. 90 and its depth beneath the port is equal to and shaped like the corresponding portion A of Fig. 89. Beyond the valve face the part B is a half-circle in each box. The length of the box exceeds that of the cored portion by the dotted lines indicating the core prints on Fig. 90.

Finishing Patterns. A pattern should be made hard and smooth so that it can be easily drawn from the sand. It should be protected by a coating that will not be affected by the moisture contained in the sand. Shellac varnish is a good material for such a coating.

In the finishing of a pattern it should first be sandpapered smooth. It is then given one coat of shellac varnish. This will roughen the wood and after the varnish is dry a second sandpapering will be required. Then a second and sometimes a third coat of varnish is laid on, when the pattern will be ready for the foundry. Never put on a coat of shellac until the previous one is perfectly dry and hard. Let the varnish dry slowly in the air and do not hasten it by putting the pattern near a stove or heater. An hour is usually quite sufficient to harden a coat of shellac varnish.

Parts where slivers or small pieces have been chipped off may be mended with beeswax. It is best applied with the warm blade of a knife. Hold the blade in an alcohol flame or that of a Bunsen burner for a moment and then cut off a bit of wax which will melt on the blade and may be rubbed into the broken part of the pattern; the process being repeated until the break is filled.

Paint and ordinary varnish should not be used on patterns.

Files are frequently of service in finishing patterns; the half-round being a particularly convenient tool.

SECTION 2.

FOUNDRY WORK.

The art of making iron castings has been brought to its present state of excellence after many years of labor and experiment. Iron in its natural state exists as ores and to be of use to man it must first be smelted to a form that is known as pig iron. In this state it may be puddled or wrought to convert it into wrought iron or steel. Iron, as steel or wrought iron, was known for many centuries before iron castings were made.

There are records of many attempts to make iron castings but there is nothing of importance recorded until 1544 when a patent for making iron castings was granted in England.

The art of making iron castings first became successful about the beginning of the eighteenth century. At this time the primitive cupola was invented. It consisted of a crucible upon which a stack was set. The whole was filled with coal and iron as is done to-day with the cupolas. A blast of air was forced in over the top of the crucible. After it was filled with melted iron the stack was knocked away, the debris cleared, and the melted iron from the crucible poured into the moulds.

About the same time a method of leading off gases from the moulds was discovered at the Darby furnace in Colebrookdale. From this time the art of moulding steadily advanced. The introduction of the steam engine in the last half of the century, materially assisted in the development.

The methods employed in the converting of pig iron come under the subject of Metallurgy. After the pig iron has been run it is remelted in a cupola and then is ready to be made into iron castings. The process of remelting and pouring the melted iron into moulds will be discussed in the following pages.

The Foundry is the name applied to the building, cupola and all the tools and appurtenances that go to form the equipment needed to make iron castings. Of these the cupola is the most important.

The Cupola is the furnace in which the iron is melted. In general construction it resembles the blast furnace in which the pig iron is made. The difference is one of size rather than of principles of construction or operation. There are many patented cupolas but these patents relate, for the most part, to details and do not affect the general construction. The ordinary foundry cupola, as usually built, consists of a shell of wrought iron riveted in the same manner as the shell of a boiler, and lined with firebrick. It is set on end and the bottom is formed of two doors opening downward. A blast of air is admitted above the bottom; fuel and iron are thrown in at the top. Fig. 1 is a vertical section of an ordinary cupola. In this engraving B is the wrought iron shell which contains the firebrick lining and holds the latter in place. The thickness of the plates of the shell varies from $\frac{1}{4}$ to $\frac{1}{2}$ inch according to its diameter. The thickness for one of 45 inches diameter should be $\frac{3}{8}$ inch. This shell and the firebrick lining usually stand upon a strong cast iron base, which in turn is supported by four columns. These are carried on a stone or masonry foundation and are of sufficient length to raise the base three or four feet above the floor.

The lining of the cupola should be made of firebrick. The best method is to use two layers, each 4 inches thick. When the inside layer has burned through it may be renewed without disturbing the one next the shell. Ordinary red brick is sometimes used for the layer next the shell but it is unreliable and used only on account of its cheapness. In lining a cupola the bricks used should be moulded to fit the circle of the shell and should be packed as closely together as possible. The spaces between them should be filled with fire clay but only enough should be used to make an air-tight joint. The smaller the amount of clay used the better. To obtain the best results prepare the clay by making a thin mixture with water. Dip the brick into this mixture before setting, and enough clay will adhere to make the joint. After the brick is put in position rap it sharply with a wooden mallet in order to force all superfluous clay from between the joints. A lining put up in this way will last twice as long as where thick clay is used. The nominal diameter of a cupola is the diameter inside the lining. Hence the inside diameter of the shell should

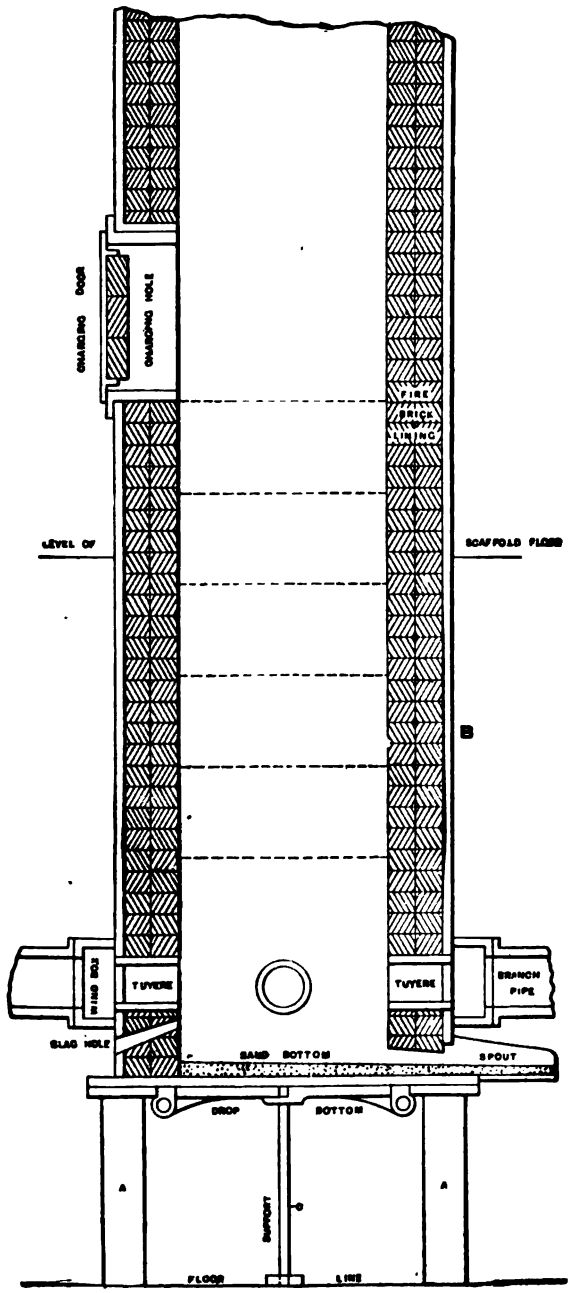


Fig. 1. The Cupola.

be 16 inches larger than the diameter of the cupola. This may be less for very small cupolas. For such six inches of firebrick will be a sufficient thickness of lining.

Sometimes cupolas are so built that the iron and fuel must be thrown in at the top. The ordinary construction, however, is such that the shell and lining are carried high enough to prevent danger of fire from escaping sparks. In this case a charging door is placed in the shell at a convenient height above the bottom. The distance from the base to the bottom of the charging hole is known as the height of the cupola.

The height of the cupola varies with the diameter. For small cupolas the greater the diameter, the greater the height. An approximate formula for determining the height of a small cupola is,

$$H = D \times (6 - \frac{D}{2})$$

in which,

H = the height of the cupola in feet,

D = the diameter of the cupola in feet.

EXAMPLES FOR PRACTICE.

1. What should be the height of a cupola 24 inches in diameter? Ans. 10 feet.

2. What should be the height of a cupola 36 inches in diameter? Ans. 13 feet 6 in.

3. What should be the height of a cupola 72 inches in diameter? Ans. 18 feet.

It may be noted that it is unnecessary to pay any attention to the odd inches in such problems and that the nearest even number of feet may be used. The heights may also be varied from those given to suit various conditions.

The Base of a cupola is usually a square plate of cast iron having a circular hole in the center of the same diameter as the inside of the lining. It is smooth on the upper surface with the exception of a low ring in which the shell is set. The bottom is provided with pockets for the reception of the columns by which it is carried. Lugs are also cast on the lower side to form the

hinge connections for the doors. The doors are also of cast iron and are of sufficient strength to carry the load put upon them. One has a lip cast upon it so that a closed surface on the lower side is presented. There is no latch or other means of holding the doors except a prop C which is knocked away when the bottom is to be dumped.

The Windbox is a belt or pipe surrounding the shell a short distance above the bottom. Air from the blower enters the windbox before entering the cupola. The openings from the windbox into the cupola are called *tuyeres*. The location, form and size of the tuyeres have been determined by experiment. They are made square, rectangular, triangular, round and elliptical. Each form has its advantages, although the size and distribution are of more importance than the shape. The distance from the bottom depends upon the work to be done. Low tuyeres have the advantage of effecting some saving in fuel. For ordinary jobbing shops a height of 10 inches from the base to the bottom of the tuyeres will give good results. This applies to all diameters of cupolas. The total area of the tuyeres varies with the size of the cupolas. The following table gives the total tuyere area for cupolas ranging from 24 to 72 inches.

Diameter of Cupola.	Area of Tuyeres.	No. of Tuyeres.
24 in.	24 sq. in.	2
30 in.	75 sq. in.	3
36 in.	108 sq. in.	4
42 in.	174 sq. in.	6
48 in.	204 sq. in.	6
54 in.	312 sq. in.	8
60 in.	400 sq. in.	8
66 in.	440 sq. in.	8
72 in.	550 sq. in.	10

For sizes with a greater diameter than 60 inches it is customary to keep the diameter 60 inches at the windbelt or tuyeres and increase to the full diameter of the cupola above. This is done because a diameter of more than 60 inches at the tuyeres does not permit the air to reach the center of the cupola, the result of

which is imperfect combustion. This form of construction is shown in Fig. 2.

The iron is drawn out of a spout, located at the bottom of the cupola as shown in Fig. 1. A peep hole is placed in the wind-box and covered with mica through which the amount of accumulated iron may be noted.

Melting Iron. We now come to the preparation of the cupola and the melting of the iron. The first thing to be done is to

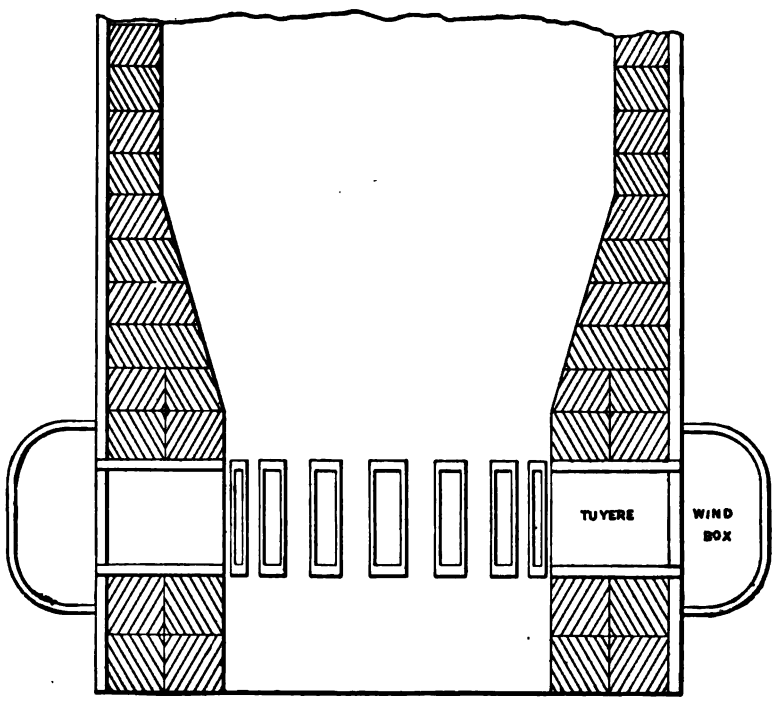


Fig. 2.

enter the cupola and daub the places of the lining that have been burned away. Fire clay mixed with a small quantity of sharp sand is used. It should never be put on in greater thickness than one inch. When this is insufficient to prevent the shield from becoming red hot the cupola should be relined. After the inside has been cleaned of adhering slag and daubed, the bottom doors are closed and propped. Upon the bottom a protection of sand

and cinders is placed and rammed down. It is then coated with a thin layer of fire clay to prevent its washing away. The front is built up with fire clay and the spout lined with the same. It is best to build a small fire of charcoal in the spout, to dry it, before the charge is put in.

The Bed is the name applied to the fuel that is first put in the cupola. The work of forming the bed should be carefully done. First some shavings are placed near the tap hole and upon these enough perfectly dry wood to ignite the main fuel. Either coal or coke may be used for the bed. The depth will be less with the former than with the latter. If coal is used Lehigh lump anthracite will be found to be the best. If coke, use large pieces of Connellsville. The bed should be made 12 inches thick for coal and 18 inches for coke.

Charging. The first charge or layer of iron is thrown in on the bed. It usually amounts to about three times the weight of fuel. Thus, in a 42-inch cupola, the bed would consist of about 520 pounds of coal upon which 1,560 pounds of iron would be thrown for the first charging. If the cupola is in good working condition the successive charges may be in the proportion of about one pound of fuel to 9½ pounds of iron. Thus, for a 42-inch cupola the charges should consist of about 400 pounds of fuel and 3,800 pounds of iron.

Melting. After the cupola has been filled with alternate layers of fuel and iron to the charging doors, it is ready for lighting. As the cupola has been daubed with damp materials, it is necessary that it should be dried before the blast is put on. The fire is, therefore, usually lighted at the vent hole about an hour and a half or two hours before the pouring is to begin. This kindles the bed, heats the cupola and first charge of iron; besides it either ignites or heats the fuel above. About twenty minutes before pouring is to begin the blast is put on.

The Blast is usually supplied by a fan blower which should be driven by an independent engine. The pressure of the blast is dependent on the size of the cupola. It varies from 6 to 16 ounces per square inch. The lower pressure may be used on 24-inch cupolas and the higher on 72-inch. It is necessary that the pressure should be sufficient to carry the air to the center of the

cupola. For a cupola 42 inches in diameter the pressure should be 10 ounces.

In about five minutes after the blast has been applied the iron will begin to "come down." As the tapping hole is still open the iron first melted will flow out. This should be allowed to continue for a few minutes. The first iron to come down is not very hot. If the tapping hole were to be plugged at once, the iron would chill over the inside and choke it. When the iron is flowing freely the tapping hole is plugged with a piece of fire clay. This is done by fastening the clay on the end of a rod and jamming it into the hole. When this has been done the melted iron will accumulate in the bottom of the cupola and the lowest layer of fuel will float upon it. Strict watch is kept through the peep hole and when a sufficient quantity has been melted to fill the ladles, an iron bar is rammed through the tapping hole and the iron drawn off. When the cupola has been emptied the hole is again plugged so that the iron may accumulate.

As the iron comes down and the fuel is burned, fresh charges of both in alternate layers are thrown in at the charging door.

After all the iron of the last charge has been melted and drawn off and all the fuel burned, the prop supporting the bottom doors is knocked away. These fall and the contents of the cupola is dropped upon the floor, whence they must be cleared away after cooling.

Besides the fuel and iron that are used for melting, it is sometimes advantageous to use a flux. A flux is "a substance that promotes the fusing of metals." The object of using a flux in a cupola is to separate the impurities from the iron as well as to make it more fluid. The materials most commonly used for this purpose are oyster shells and marble chippings. Limestone, as in blast furnaces, is also used. The proportion to be used is about six pounds of oyster shells per melted ton of iron. Where the iron is clean and it is not necessary to use a flux it will be found advantageous to throw in a shovelful of oyster shells or marble chippings. This helps clean out the cupola.

Sand. The greater portion of all foundry moulding is done in sand. The sand used for this purpose must have certain peculiar properties. It should have a uniform grain, have some adhesive

qualities, and be infusible at high temperatures. A failure to possess the first quality will make even ramming difficult or impossible. If it will not adhere, when rammed, the mould will fall to pieces. If it is not infusible, it will melt under the high temperatures to which it will be subjected and ruin the casting. A good moulding sand should, therefore, consist mainly of silica. Silica is one of the most infusible of the elements. The sand is made adhesive by mixing with it a little magnesia or alumina, usually the latter. It is found as an oxide of aluminum in the form of a clay. Moulding sands are found in various parts of the country. They are found in Canada, Central New York and New Jersey. Any sand containing limestone should be rejected.

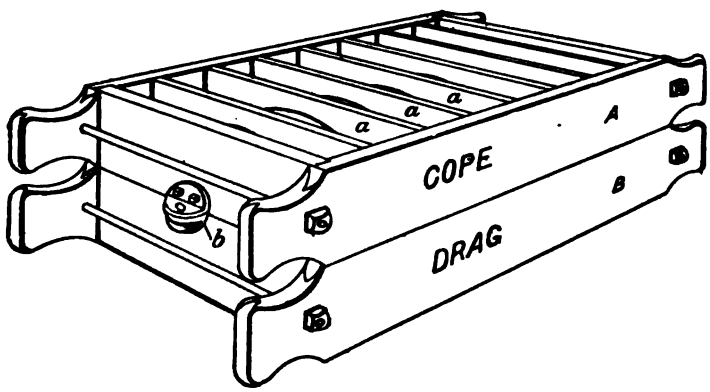


Fig. 3.

Cutting Up Sand is the process by which sand is worked into condition for use in the moulds. It is now sometimes done by special machinery. Ordinarily it is heaped in winrows across the floor of the foundry, pails of water are thrown over it and it is then shoveled back and forth until the moisture is evenly distributed. No rule can be given for the quantity of water to be used. The sand should be brought to about the same condition of dampness as that prevailing six or seven feet below the surface of an ordinary sand bank.

Flasks. A flask is the frame in which the sand is held while the mould is being made. It also usually holds the sand until the iron has been poured. They vary greatly as to form and size.

Flasks are often made of wood, but when many castings are to be made from any one pattern it is better to use cast iron. The ordinary form of wooden flask is shown in Fig. 3. The upper portion A is called the *cope* and the lower portion B is the *drag* or *nowel*. The difference is that the cope is provided with a number of crossbars *a a*. These bars provide surfaces to which the sand adheres when the cope is lifted from the pattern. The drag has no crossbars because it is only lifted or moved when there is an opportunity to clamp a moulding board on each side of it to hold the sand in position. In order to insure an accurate registering of the two parts of the flask, a dowel pin and plate is attached to each end as shown at *b* Fig. 3.

The frame of the flask should be made of sound wood about

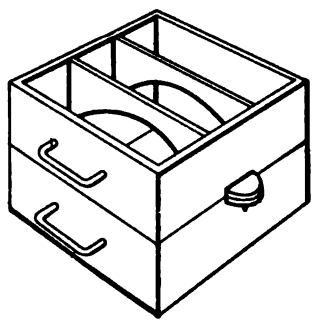


Fig. 4.

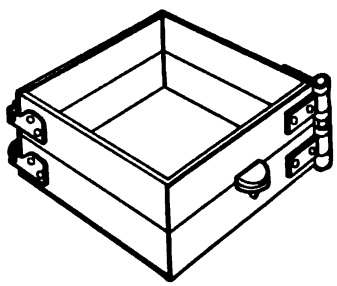


Fig. 5.

1½ inches thick and of a width suited to the size of pattern to be moulded. It should be tied together with bolts to prevent breakage. The bars are made of thinner material. They may be from ¾ to 1 inch in thickness.

Iron flasks (Fig. 4) are made of cast iron. The thickness of metal ranges from ½ inch upward, according to the size of the flask. The bars of the cope for small flasks may be made ⅜ inch thick. The edges of the drag and cope should be planed where they come together. Dowel pins should be fitted into lugs cast on the side of the flask so that the mould will always register accurately.

The size of the flask chosen for any piece of work, should be such that a thickness of from at least 2 to 3 inches of sand should

be upon all sides of the pattern. This thickness must be increased as the weight of the casting increases.

For very light work snap flasks are used. These open out and may be removed from the sand before the metal is poured. It is thus possible to make a large number of moulds in a single flask. This saves in the original investment of the foundry. An ordinary snap flask is shown in Fig. 5.

Large flasks are usually provided, both in the cope and drag, with trunnions by which they are raised and moved. They should also be strengthened at the edges as shown in Fig. 6.

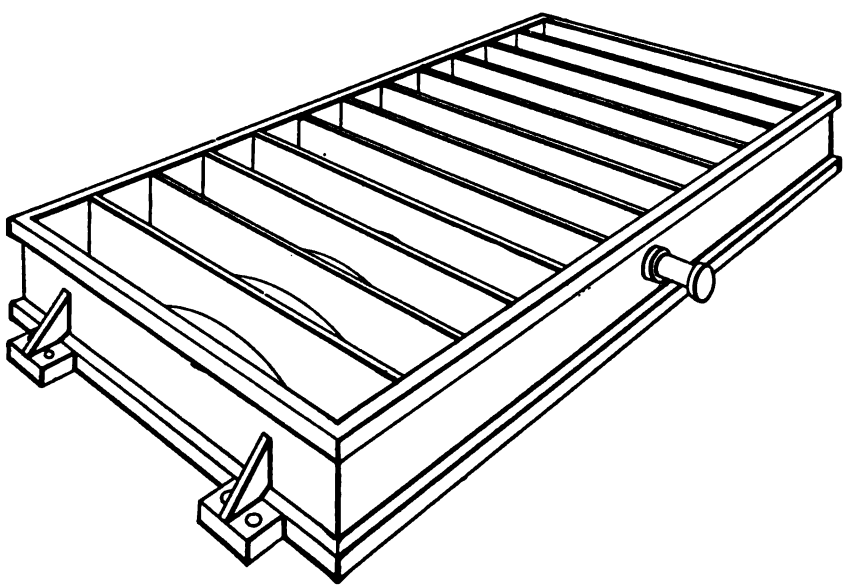


Fig. 6.

Flasks are also made with the sides hinged; for dressing they may be turned down with a portion of the sand.

Tools. The moulder's tools are of the simplest character. They should, however, be well made and receive proper care. Some are provided by the employer and some by the moulder. Those usually supplied by the employer are water pails, shovels, swabs, riddles, bellows and rammers. There ought always to be an ample supply of these tools so that no one need be idle. The pails are used for wetting down the sand previous to cutting up,

etc. The shovels are for cutting the sand, throwing it into the riddles and similar work; the swabs serve to moisten the sand in the moulds when finishing. The riddles are the sieves through which the sand is sifted upon the patterns so that when the ramming is done it will be light and even in its texture and free from lumps. The bellows serve to remove the dust and loose sand that may have accumulated in the recesses of the mould while in course of preparation.

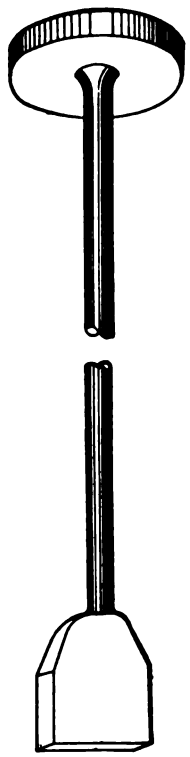


Fig. 7.

The rammers vary in length, weight and form in accordance with the work to be done. The general forms of rammers are shown in Figs. 7 and 8. The quality of the casting depends upon the weight and form of the rammer, and the force of the blow. For ramming moulds that are upon the floor a rammer as shown in Fig. 7 is used. It is usually made of iron and its weight depends upon

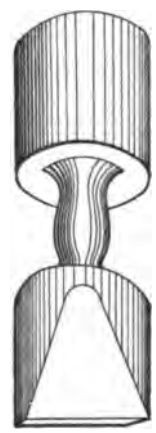


Fig. 8.

Fig. 9.

the depth of sand to be rammed. For ordinary work this weight should be about 9 pounds. One end is flattened and from 3 inches to 4 inches in diameter. The other end is wedge-shaped with a rounded edge. The wooden rammer shown in Fig. 8 is for bench work. When such rammers are used one is usually held in each hand. It is, therefore, used for light ramming of small work on a thin body of sand.

The tools of the moulder's personal kit are small, light and

simple. First he should have a liberal supply of vent wires of various sizes. These should be from $\frac{1}{16}$ inch to $\frac{1}{4}$ inch in diameter. They are made of ordinary stiff iron or steel wire flattened at one end and filed into the shape of a spear head as shown in

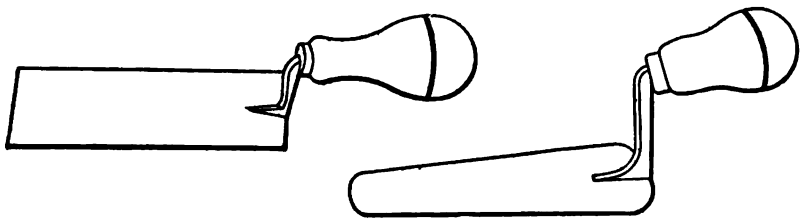


Fig. 10.

Fig. 9. His next implement is the trowel (Fig. 10); this tool is in constant use. Each moulder should have at least four of different sizes. Its blade is square or with a rounded end. It should be stiff with a perfectly smooth flat surface. The lengths should be from 4 to 7 inches. Such a trowel is used for slicking off flat surfaces. When it becomes worn and pliable it may be used on curved surfaces. Another form of trowel is of the heart-shape (Fig. 11). The blade of this tool should be about 3 or 4 inches

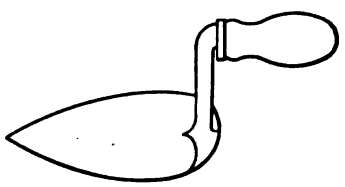


Fig. 11.

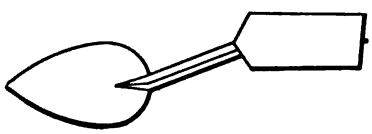


Fig. 12.

long. It is used for slicking off corners that cannot be reached with the square trowel. A combination form of heart-shaped and square trowel is shown in Fig. 12. This is usually a light tool with blades from 2 to 3 inches in length. Smoothers with the handle set at an angle as in Fig. 13, serve the purpose of the trowel where the mould cannot be reached by the latter. They should be from $\frac{1}{2}$ inch to 2 inches in width. Sometimes they are made with loose ends that can be screwed upon shanks.

Lifters, as shown in Fig. 14 are important tools. They are used for *sleeking* and smoothing such portions of the mould as cannot be reached by the trowel. Their name is derived from

their use, that of lifting out portions of sand that may have broken off from the mould. A modified form of smoother intended for rounded surfaces, and called a bead tool is shown in Fig. 15.

Still other forms of smoothers are shown in Figs. 16 and 17. These are for working into and over corners. Sometimes they are made with a concave or convex surface as shown in Figs. 18 and 19 and 20.

These are the principal types of tools used. They are of

Fig. 13.

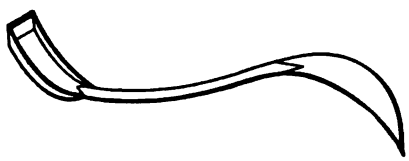


Fig. 15.

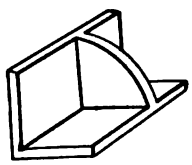


Fig. 16.

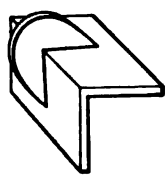


Fig. 17.

Fig. 14.

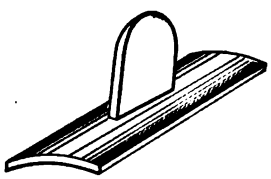


Fig. 18.

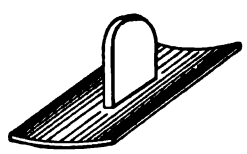


Fig. 19.

almost infinite variety of shape and design dependent upon the class of work. Where a moulder is engaged exclusively on one class of work he will need special tools, of the above general forms. These can best be designed to meet the necessities of the work in hand.

Moulding Sand. The qualities of ordinary moulding sand have already been given as infusibility and adhesiveness. Such sand, when used in its natural condition is called green sand. Green sand moulding is most extensively practiced. In many foundries it is used exclusively.

Loam is usually made in the foundry where it is used. It consists of sharp sand, moulding sand, manure and clay wash. The best way of mixing the loam is by the use of a mill. Loam mixing mills are practically the same as flour mills. Each has its upper and lower stones. Grindstones are, however, used instead of burr stones. When the loam is mixed by hand the mixture is beaten with an iron rod as it lays upon an iron or wooden bench. The mill is the better means of mixing.

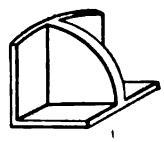


Fig. 20.

The ingredients of loam vary with the purpose for which it is intended and also with the method of mixing. When ground in a mill a good proportion is: sharp sand 7 parts, manure 2 parts, moulding sand 2 parts, mixed with a thick clay wash. Clay wash is made by stirring ordinary blue clay in water. A thick wash is obtained by using a surplus of clay, and stirring frequently. When the loam is mixed by hand the proportions vary somewhat. They should be: sharp sand 5 parts, moulding sand 2 parts and manure 1½ part, mixed with a thick clay wash. The sharp sand is used as a regulator for the moulding sand. The more clay there is in the moulding sand the greater the quantity of sharp sand that must be used. Experience alone can tell the exact ratios. A skilled workman can tell by the feeling as to whether the loam is properly mixed or not. A practical test is to take a well-dried lump and drop it in molten iron. If the iron boils after the first bubble, the mixture is too dense and contains too much clay. In this case more sharp sand must be added.

Dry sand is the name applied to a class of moulding where the moulds are baked in an oven before being used. The most common example of dry sand moulding is that of cores. The great majority of all cores used are made of dry sand. Loam cores are sometimes used in green sand moulds. Dry sand cores and moulds are made of sharp sand with a binder to cement the grains

together. Good sharp sand should be free from clay. The grains should stand out separately and distinct from each other. It should consist, as nearly as possible, of pure silicon. The best of sharp sand may be obtained from any of three sources; the beach where it has been washed by the waves of the ocean; river beds, where it has been cleansed by the scouring action of the stream and the artificially washed sand taken from banks.

The binders used as cement for cores are beer, flour, molasses, resin, clay and glue. Those in most common use are flour and molasses. As in loam moulding, the proportions of the ingredients used in cores vary with the work to be done. A good common mixture is the following: 1 part flour, 7 parts clean sharp sand and 3 parts fine moulding sand, mixed with enough water to dampen. A tougher core can be made of 12 pounds of sharp sand, 5 pounds of moulding sand, 2 pounds of very finely ground resin and $\frac{1}{4}$ pound of flour. This should also be mixed with water in which molasses has been stirred in the proportion of 1 gill to the quart. The ingredients should be carefully mixed so that each portion is evenly distributed throughout the mass.

Cores are made in core boxes. The construction of these boxes is fully described in "Pattern Making." After the core mixture is made it is rammed into the core boxes, turned out on the bench and then carefully and thoroughly dried in a core oven. As already stated in "Pattern Making" cores are frequently made in halves and pasted together. The paste is made of a cheap grade of wheat flour. After the core or dry-sand mould has been dried it should be blackened so as to present a smooth surface to the iron. The blacking may also be applied before the core is baked. Preparation of the blacking calls for the same skill as that of the core and loam mixing. A good blacking may be made of 1 pound of black lead, 1 pound of charcoal blacking, 4 pounds of Lehigh blacking, mixed with beer or molasses water and a little fire clay. In mixing molasses water for this purpose, use about one-half a pint of molasses in a pail of water.

Core ovens are used for drying cores and moulds. There are many styles of ovens. Where large and small work is done there should be two ovens for the two classes of work. It is uneconomi-

cal to heat a large oven in order to bake small cores. The oven and fireplace are usually in the same enclosure. Thus the products of combustion come in contact with the cores without injury to them. A convenient form of oven for baking small cores is shown in Fig. 21. It consists of a number of circular shelves mounted on a central shaft which is held by a step at the bottom and a bearing at the top. By turning the shelves any parts of them may be brought opposite the door for loading or removing the cores.

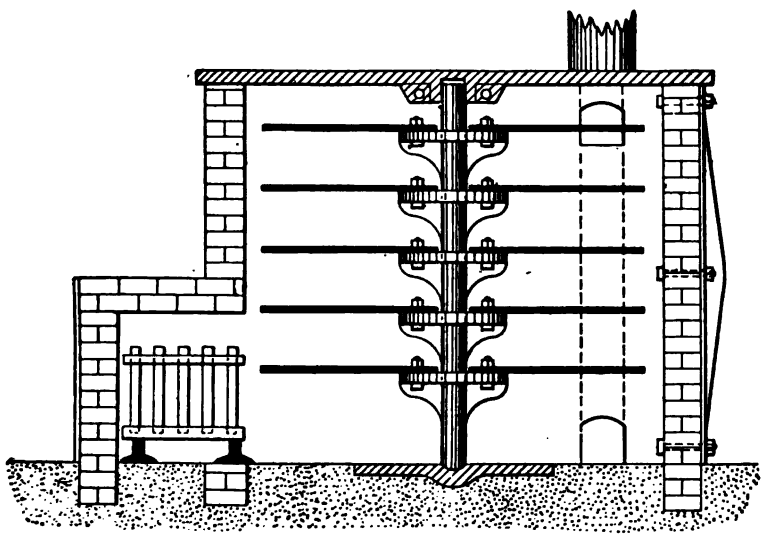


Fig. 21

The shelves should be in the form of gratings so that the hot gases may pass through and around the cores. The furnace and stack should be arranged so that the hot gases and products of combustion are made to pass across the oven.

Large ovens are made with a traveling carriage. The cores are loaded when the carriage is outside the oven. The carriage is then run in, the doors closed and the fire lighted. Such an oven is shown in Fig. 22. The furnace is located beneath the floor of the oven. There are racks upon each side upon which cores may be dried as well as upon the carriage.

Firing. The best fuel for firing a core oven is coke. Wood

is very frequently used, as is also hard and soft coal. It is desirable to have a steady fire. Wood and soft coal do not make steady fires and they require constant attention. Hard coal makes a good, hot fire, but it is expensive. The time required to dry a core varies from one to fourteen or more hours, according to its size. Where large cores are to be dried it is customary to bake

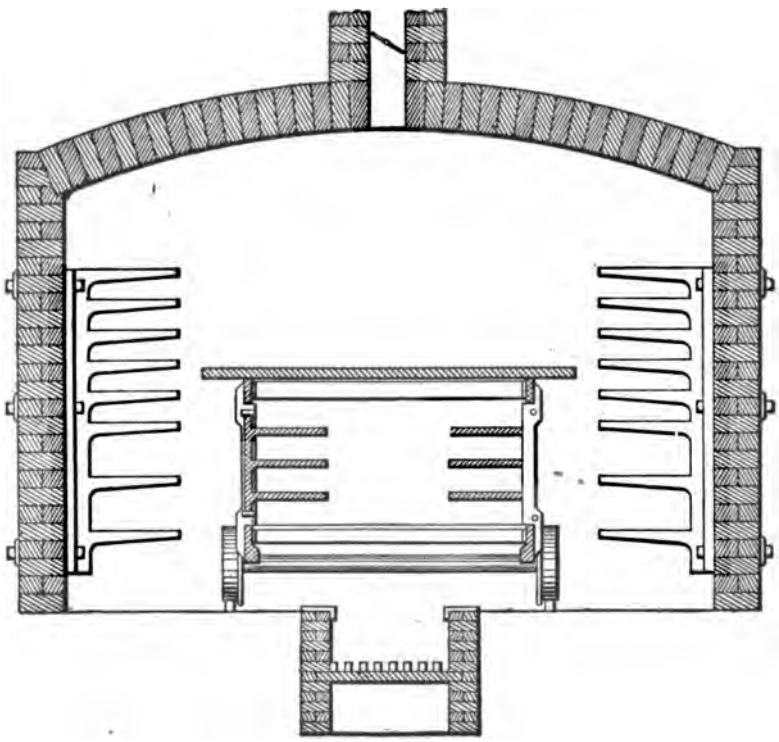


Fig. 22.

them all night. In such cases the dampers of the furnace must be arranged so that the fire will burn steadily for a long time without attention.

Dry sand moulds are baked in the same way as cores, except that, in some instances they are dried in position. Loam moulds are also dried in position.

Moulding. The work of the moulder differs from that of the carpenter, blacksmith or machinist. The blacksmith can see with

each blow of his hammer how his work is progressing; the machinist has his work constantly under his eye so that he sees just what is being done even with the finest cut. But with the moulder, the progress of his work to some extent is not visible. He makes his moulds and cores but the progress of his work cannot be fully determined until the casting is completed. For this reason the moulder must work with great care; his skill comes largely from his own experience and that of his fellows. Knowing "the reason why" is of as much benefit in this work as in any other.

It is impossible to give explicit directions as to the force of the blow to be given to the rammer. This must be left to the judgment of the workman. He will soon learn to gauge the blow according to the work to be done. The general principles of ramming may be roughly stated to be;

The deeper the body of sand the harder the ramming.

The hardest ramming must be done near the lowest point of the sides of the moulds.

The lightest ramming should be done near the highest point of the sides of the mould.

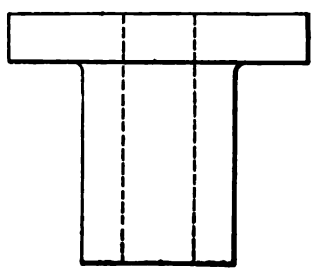


Fig. 23.

To these statements it may be added, that light ramming continued, until the sand is in a proper state of compactness, will give better results than hard ramming for a shorter time. Evenness in the blows is of the greatest importance. Any bottom section of a mould that is to have a pressure put upon it by a rapid flow of molten metal will stand harder ramming than where it is to be covered over slowly. Hard ramming causes more trouble than light. The rammer should never be allowed strike the pattern.

The general method of making a mould is the same for all patterns, but there is an endless variety in the detail. As a simple example take the gland illustrated in Fig. 56 of "Pattern Making" and reproduced here in Fig. 23.

First select a flask of a suitable size. It should be at least 8 inches larger each way than the diameter of the pattern, and $2\frac{1}{2}$ inches deeper. This leaves 4 inches of sand upon each side and $2\frac{1}{2}$

inches at the bottom. The flask consists of the two parts, the cope and drag or nowel to which must be added a moulding board. This moulding board is used repeatedly for successive moulds. It consists of smooth boards fastened together with cleats as in Fig. 24, and has one plain surface. The moulding board is laid in a level position on the floor with the plain surface uppermost. The

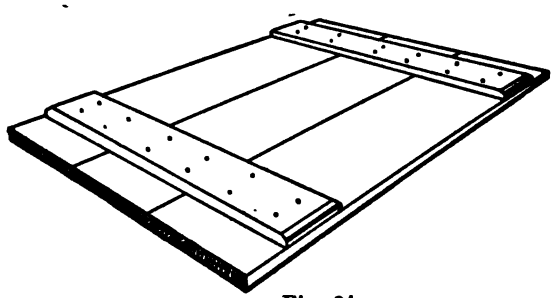


Fig. 24.

pattern is placed in the middle of the board, with the side down which is to be at the parting line between the cope and drag. The drag should then be set on the moulding board (Fig. 25) bottom up. It must be adjusted so as to stand evenly about the pattern. Fill a riddle with sand and sift it over the pattern until it is entirely covered. Where there is to be a core formed of green sand, as in this case, the hole in the pattern must be filled with

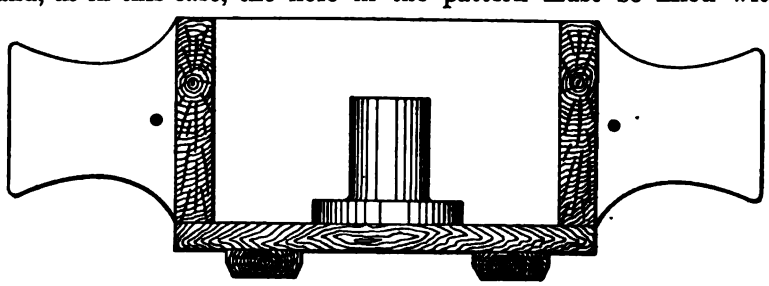


Fig. 25.

sifted sand. Tuck this sand down snugly into the hole before commencing to ram. When the ramming is completed scrape off the sand that projects beyond the edge of the drag, lay another board on top to hold the sand in position, and clamp the drag and the two boards together as in Fig. 26.

The **clamps** used for this purpose should be strongly made of

iron about 1 inch square and of the shape shown in Fig. 27. They should be long enough to slip easily over board and drag and be held by wedges driven in as shown in Fig. 26.

When the drag and moulding boards have been clamped together the whole should be turned over and the moulding board

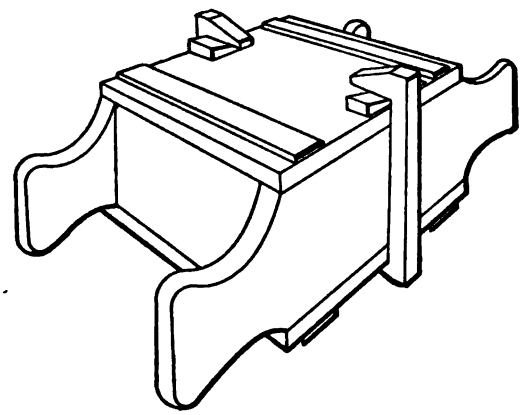


Fig. 26.

removed. This exposes the surface of the sand with the pattern on top. Examine the mould carefully to see if the sand lies close about the edges of the pattern. If it does not, mend it by the addition of sand where needed. Do this work with the fingers and only use the trowel for smoothing.

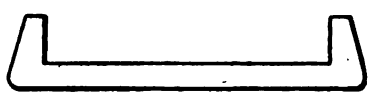


Fig. 27.

After this face of the mould is made all right, sprinkle the whole surface with *sharp* sand, which is then called *parting* sand. This will prevent the sand of the cope from adhering to that in the drag. If the sand adheres the cope and the drag can not be separated and the pattern removed without injuring the mould.

After placing the cope in place, sift in enough sand to cover the upper surface of the drag, then shovel in enough to fill the same and ram. In ramming the cope be careful that the rammer does not strike the bars.

When the cope has been rammed and the superfluous sand removed from the top, it is lifted off and laid bottom up. The parting sand is then dusted from the faces of cope and drag. The

pattern may now be removed. It is usually advisable to wet the swab and draw it around the edge of the pattern. This stiffens the sand and prevents it from breaking away when the pattern starts. Great care should always be exercised in the use of the swab. If too much water is used it will cause blowing when the iron is poured. If it is necessary to make the sand very damp, it should be dried somewhat before pouring. The pattern is lifted out of the sand by screwing a lifter into the lifting plate, if there is one. If no lifting plate has been put on the pattern, a sharp pointed lifter is driven into the wood. This is rapped gently to

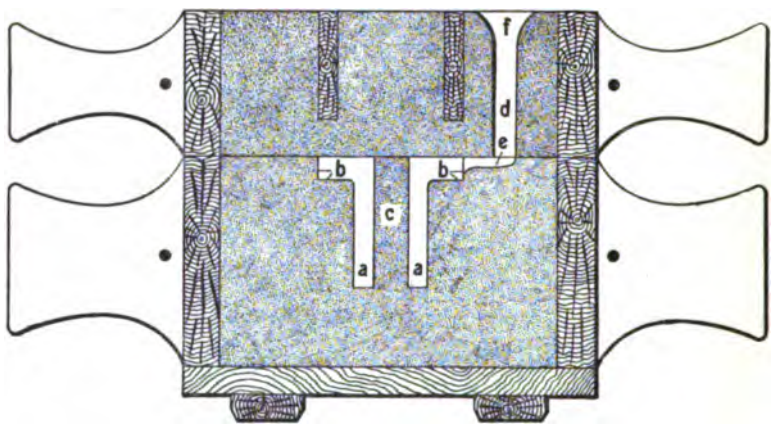


Fig. 28.

and fro, while being pulled. As soon as the pattern starts the rapping may stop. Be careful that the pattern is lifted vertically and does not strike the surface of the sand. The mould is now made and only requires finishing and blacking.

Blacking is a mixture of anthracite coal, charcoal and black lead, all especially prepared for the purpose. A good mixture may be taken as 2 parts of Lehigh blacking, 1 part charcoal blacking, and 1 part of German or American black lead. The blacking may be applied either wet or dry. When applied dry it is put in a cotton or coarse linen bag and dusted over the surface of the mould. When blacking is to be applied moist it should be wet with beer or molasses water. It is applied with the swab. The object of blacking is to give a fine, smooth surface to the face of the casting and to prevent the sand from adhering to the metal.

In the case of the moulding of the gland, where the metal is light the blacking is usually applied dry because the parts *a a* (Fig. 28) in the depth of the drag are not accessible either to the swab or the smoothers. After the blacking has been shaken over the whole surface of the mould the exposed parts *b b* (Fig. 28) may be sleeked over with the smoothers. The mould may then be closed, as shown in section, Fig. 28. In which it will be seen that the mould is wholly imbedded in the drag. The core is formed by the green sand *c*. The cope serves merely as a cover to prevent the overflow of the iron.

The passage by which the molten metal reaches the mould is made through the cope. This is done while the cope is being rammed. A stake (Fig. 29) about 1½ inches in diameter and long enough to reach to the top of the cope is stuck in the upper surface of the sand of the drag. This projects up through the cope and the sand is rammed about it as though it were a pattern. Before the cope is lifted off this is pulled out leaving a hole in the sand of the cope as at *d*, Fig. 28. From the bottom of this hole a groove *e* is cut out of the sand leading to the mould. The top of the hole *f* is usually enlarged so as to secure a wider opening into which to pour the metal. The gate *d* should not lead directly into the mould. The force of the falling metal dropping upon the face of the mould would wash it away and ruin the casting. This is called the gating of the casting. There are many ways of gating that are adapted to different classes of work, some of which will be described later.

Fig 29.

After the mould has been closed as in Fig. 28, the cope and drag must be clamped together. This is done in the same way as shown in Fig. 26 where the drag and two boards are clamped together. Clamping is only used on small moulds. In large moulds the cope is held down by weights.

Weighting or clamping is necessary in order to prevent the upward pressure of the molten iron from forcing apart the cope and drag or floating the former. The upward pressure on a cope depends upon the height of the iron above the upper surface of the mould and the area of the latter. Thus in Fig. 28 the

upward pressure on the cope depends upon the height of the top of the gate at *f* above the top of the flanges at *b* and the surface of the latter. The reason for measuring to the top is, that the gate is always filled with metal when pouring which is allowed to cool with the casting. This metal is afterwards broken off and remelted. It is called a *sprue*.

To Calculate the Upward Pressure on a Mould. The upward pressure of molten iron upon a mould is calculated in the same way as the upward pressure of water upon any object submerged in it. The upward pressure of water is calculated by multiplying the height in feet, by the weight of a cubic foot of water and this product by the area in square feet upon which the pressure is exerted. Iron is 7.2 times heavier than water and the cubic inch is used as the basis of calculation. The rule, therefore, to calculate the upward pressure of molten iron is: *multiply the depth in inches by the weight of a cubic inch of iron and this product by the area, in square inches, upon which the pressure acts.* The weight of a cubic inch of cast iron may be taken to be .2607 pound.

EXAMPLES FOR PRACTICE.

1. What is the pressure per square inch of section in a mould at a depth of $8\frac{1}{2}$ inches below the surface of the iron?

Ans. 2.2+ pounds.

2. What is the total pressure upon a circular area 6 inches in diameter and 11 inches below the surface of the iron?

Ans. 81.+ pounds.

4. What is the pressure upon a rectangular surface measuring 12 inches by 14 inches and 13 inches below the surface of the metal?

Ans 569+ pounds.

The pressure of molten iron is exerted in every direction in exactly the same manner as water. (See Mechanics, Part II, page 42). The height of the metal must be taken from the surface of the gate. Let Fig. 30 be the section of a mould. The upward pressure per square inch of section at *a* will be equal to the depth *h* multiplied by .2607. The lateral pressure per square inch at *b* is equal to the depth h'' multiplied by .2607 and the downward pressure per square inch at *c* is equal to the depth h'

multiplied by .2607. The total lateral pressure is equal to the area of the sides multiplied by the average pressure upon them. In Fig. 30, let the mould be 8 inches square, 7 inches deep and the gate (h) be 6 inches long. If b is midway between the surfaces a and c then

Area of a = 64 square inches.
Area of c = 64 square inches.
Area of b (one side) = 56 square inches.
Area of b (four sides) = 224 square inches.
Height h = 6 inches.
Height h' = 13 inches.
Height h'' = 9½ inches.

Let the gate at e be semi-circular and 2 inches in diameter, and the length at d be 1½ inches.

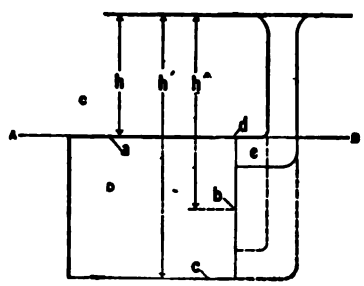


Fig. 30.

Solving this in accordance with the principles set forth we have,

Upward pressure at a=1.56+ lbs. per sq. in.

Total upward pressure on surface a = 100.11 lbs.

Average side pressure at b = 2.48 lbs. per sq. in.
Total side pressure at b (one side) = 138.69 lbs.
Total side pressure at b (four sides) = 554.77 lbs.
Downward pressure at c = 3.39 lbs. per sq. in.
Total downward pressure on surface c = 216.9 lbs.
Upward pressure on surface d = 4.69 lbs.

In Fig. 30 let A B be the parting line between the cope and the drag; C be the cope and D the drag. It is evident that the pressure at b is sustained by the sand which is held by the sides of the drag. The pressure on the bottom c is carried by the moulding board and floor. Therefore, it is only the upward pressure at a and d that must be balanced by clamps or weights in order to prevent the cope from being lifted by the iron. In the case cited this amounts to

$$100.11 + 4.69 = 104.8 \text{ pounds.}$$

Hence a weight of at least 104.8 pounds must be placed on

the cope to hold it down. Practically this should be at least 150 pounds.

If however this same pattern were to be cast as in Fig. 31 where 2 inches project up into the cope; then h becomes 4 inches and the total upward pressure at a is 66.7 pounds.

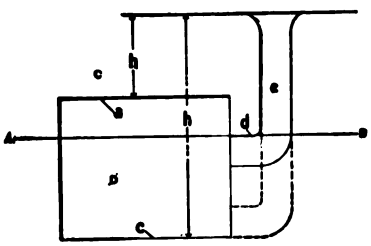


Fig. 31.

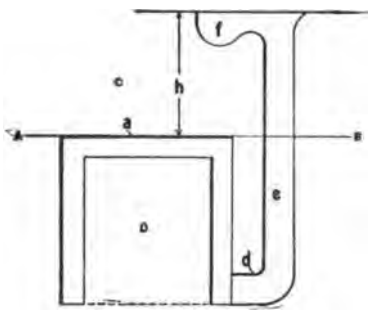


Fig. 32.

The total upward pressure on the cope is obtained by adding that at d, which remains the same as before. Hence, total upward pressure on cope $= 66.7 + 4.69 = 71.39$ pounds.

The greatest care must be exercised in these cases to determine what may be the depth of the surface acted upon below the upper surface of the gate. The way in which a pattern is moulded sometimes has an important effect upon the pressure on the cope. Suppose, in Fig. 32, we have a hollow cylinder of 8 inches outside diameter, 8 inches long and with a shell and bottom 1 inch thick. It is to be cast bottom up, with the face a on the parting line A B. Let the depth h of the gate in the cope be 6 inches. Then the pressure per square inch at a will be 1.56 pounds. As the area at a is 50.266 square inches, the total upward pressure is,

$$50.266 \times 1.56 = 78.41+ \text{ pounds.}$$

The point at which the gate enters the mould is of no moment in calculating the pressure. It is the depth of the surface below the top of the gate that is important. In Fig. 32, the surface d is 7 inches below the parting line. Hence the upward pressure at that point, per square inch, is,

$$.2607 \times 13 = 3.39 \text{ pounds.}$$

As the area is the same as in Figs. 30 and 31, the total upward pressure at d is

$$3.39 \times 3 = 10.17 \text{ pounds.}$$

Total upward pressure on cope $= 78.41 + 10.17 = 88.58$ pounds.

If now the pattern is reversed and moulded bottom down, as in Fig. 33, a different pressure will be put upon the cope. The pressure at a is that due to the height h which is 6 inches, upon a ring 8 inches outside and 6 inches inside diameter. This is 34.3 pounds.

The pressure upon a' (the bottom of the cylinder) is that of a circle 6 inches in diameter, submerged to a depth of 13 inches below the upper surface of the molten metal. This amounts to 95.85 pounds. We therefore have,

Upward pressure at a	34.30 pounds.
Upward pressure at a'	95.85 pounds.
Upward pressure at d	10.17 pounds.
Total upward pressure at cope	140.32 pounds.

This is a difference of 51.74 pounds due solely to the method of moulding.

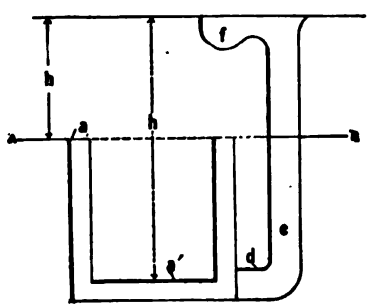


Fig. 33.

For light moulds no weight is needed. The two parts of the flask may be held together by clamps as in Fig. 26. In larger moulds, where the pressure would be apt to push the sand up out of the cope, weights must be used. The amount of weight to be used should be at least 50 per cent. more than the calculated pressure. The weight must resist not only the calculated or static pressure in the mould, but also that due to the momentum of the inflowing metal. This latter depends upon the height of the gate and the volume of the entering metal. For safety use an excess of weight. Pig iron is usually the most convenient to use for weights.

Gating. It is as necessary that the mould shall be properly gated as that it should be properly made. The gate is the passage

left in the sand through which the metal flows to the mould. The following precautions must be taken in making the gate:

(*a*) It must be of such size that the metal shall flow freely through it without chilling.

(*b*) It must be of such shape that sand shall not be torn from its sides by the falling metal.

(*c*) It must allow the metal to enter the mould in such a manner that none of the sand constituting the latter shall be washed away.

In small castings one gate may be used. This gate may enter at the top of the mould or on the parting line between the cope and the drag. For heavier castings more than one gate must be used. The reason is that if only one were put in, it would have

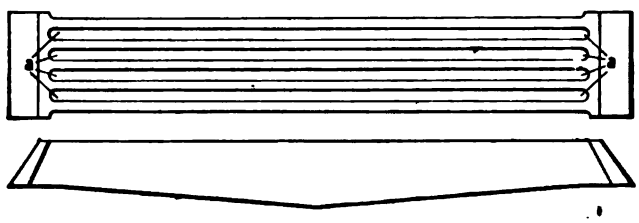


Fig. 34.

to be very large. This would involve a large inflow of metal which would wash away the sand. It is also desirable that the large moulds should be fed at different points. If the metal were poured into a large mould from one point only, it would be apt to chill before it reached all parts. This would produce a defective casting. The defect might consist of chilled parts or an incompletely filled mould. No fixed rule can be given for the number of gates. The number depends upon the size, shape and weight of the casting. The shape of the mouth of the gate also depends upon the weight of metal to be poured. For small castings it may be simply belled out as in Figs. 30 and 31. For larger castings or where the gate is deep, a basin should be formed in the sand of the cope at the mouth of the gate. Such a basin is shown at *f* in Figs. 32 and 33. The size of this basin depends upon the weight of metal to be poured.

In general it is always well to make the gates as long as possible. Where a large amount of iron is to be run through a

gate, it is well to protect the mould by placing cores against the pattern at the point where the metal will strike the sand. This may also be done by ramming a mixture of flour and facing sand against the patterns at weak points.

The size of the gate also depends upon whether the mould is to be poured rapidly or slowly. In the grate-bar Fig. 34, where there are a number of small cores, *a a*, the metal must be poured slowly. If it were to be poured in with a rush the cores would be washed away and the casting ruined. In Fig. 31 on the other hand, where there are no light cores the metal may be poured very rapidly. In Fig. 34 the iron should be poured hot and slowly. In Fig. 31 it need not be so hot and may be poured rapidly.

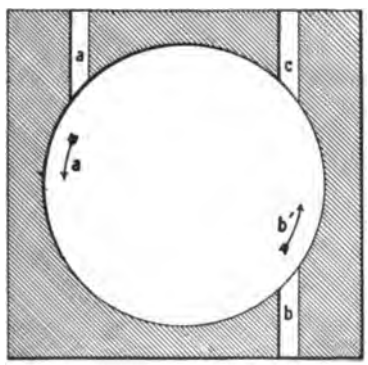


Fig. 35.

The point at which the iron enters the mould is of great importance. The method of gating shown in Fig. 33 is preferable to that of Fig. 31. In Fig. 33 the gate enters at the bottom of the mould, and sustains all the effect due to the falling of the molten metal. There is in this case little danger of washing away the sand of the mould. In Fig. 30 the iron falls from the point, where the gate enters the mould, upon the bottom *c*. The force of this falling metal will be likely to wash away the sand. This can be obviated in two ways; a dry sand core may be put in the bottom of the mould, or the gate may be led in at the bottom as shown by the dotted lines. The latter is the better method. Where moulds are very deep, even a dry sand core would be in danger of being washed away.

Where two or more gates enter a mould they should do so in such a way as to promote a circulation of the iron. An example is given in the round plate Fig. 35. If there are two gates entering at *a* and *b*, it is evident that they will have a tendency to cause the metal to circulate in the same direction, as indicated by the arrows *a'* and *b'*. If, however, the gates are placed at *b* and *c* the

currents of entering metal strike against each other. This checks the flow and retards circulation.

Where the flow of metal is very rapid, the entrance to the mould may be made through a dry-sand core.

Sometimes it is advisable to have the gate enter the mould at the bottom. The advantage lies in the fact that the upward current of metal has little or no tendency to wash away the sand of the mould. Such a case is shown in Fig. 36. Here the gate enters through a dry sand core as at *a*.

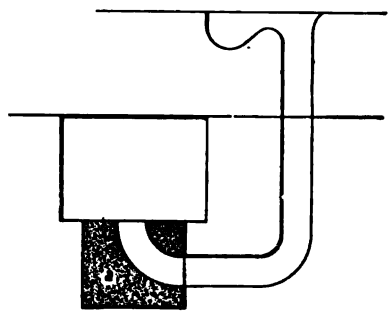


Fig. 36.

Weight of Castings. The probable weight of castings is obtained by estimating the volume; then, *multiply the contents or volume in cubic inches by .2607.*

It is important that the moulder should know the weight of his castings in advance. The melter must know how much iron to melt. If the moulder has a ladle that is too small the casting will be spoiled. If he has one that is too large, the iron will be wasted.

For simple castings where there are no cores and the pattern is made of white pine, the weight of the casting may be obtained by multiplying the weight of the pattern by 16. The reason for this is that cast iron weighs about 16 times as much as pine, bulk for bulk. This is approximate only, for it takes no account of the presence of nails, screws or rapping plates. Neither does it take into account the moisture that may still remain in the wood. This, however, will make the calculated weight of the casting greater than the actual weight, and is thus on the side of safety.

EXAMPLES FOR PRACTICE.

1. What is the weight of a flat plate of cast iron, 2 feet square and $1\frac{1}{2}$ inches thick? Ans. $225\frac{1}{4}$ (nearly) pounds.

2. What is the weight of a cast iron cylinder 24 inches long; 12 inches outside diameter and 8 inches inside diameter?

Ans. 393.15 (nearly) pounds

In calculating the amount of metal to be melted or poured an allowance must be made for the weight of the sprues that fill the gates and are attached to the castings. These weights must be added to that of the castings. Where there are cores they must be deducted from the calculated weight.

Venting. The gases formed by the molten iron must be allowed to escape from the mould. The gases are produced by the decomposition of the organic matter contained in the sand and cores. This is due to the heat of the molten iron. Unless the gases are allowed to escape they will hold back the iron and cause an irregular casting. A larger quantity of gas is formed from dry than from an equal weight of green sand. This is due to the presence of a larger amount of organic matter, such as flour, molasses, etc., in dry than in green sand.

Venting is usually accomplished by pushing a vent wire (Fig. 9) through the sand of the cope at several places. The larger the dry-sand core used the greater the number of vent holes. Venting is very important in moulding. When it is found that the gases pass up through the iron, causing it to bubble at the mouth of the gate, the venting is insufficient. If a mould is rammed solidly the number of vent holes must be large. When sand has been used a number of times the organic matter is largely decomposed. Hence, old sand will produce less gas than new, and therefore, requires less venting. The venting should be done while the pattern is still in the mould. If the venting is not properly done, the pressure of the gas may be sufficient to throw the metal out at the gate.

Pouring. After the metal is melted it is drawn from the cupola into a large ladle. From this large ladle it is poured into smaller ones. These are taken to the moulds and emptied. They vary in size from the small hand ladle that may be carried when filled, by one man, to the ladle holding several tons that is moved by a crane. The iron as it comes from the cupola is usually too hot to be poured immediately. Cast iron melts at about 1500° Fahr. It is usually much hotter than this when it leaves the cupola; also when poured. The temperature at which it should be poured depends upon the kind of casting to be made. No definite rule can be given, but it is customary to have the metal at higher

temperatures for the thinner castings. Moulds having thin cores or projections should be poured slowly with hot metal. Heavy castings with few or no cores may be poured rapidly with dull metal.

Ladles. As already stated, ladles are of all sizes. The ordinary ladle is made of cast iron and is freshly lined after each casting with fire clay. This lining is called *daubing*. The fire clay is mixed with water until it is in a plastic condition like putty. The

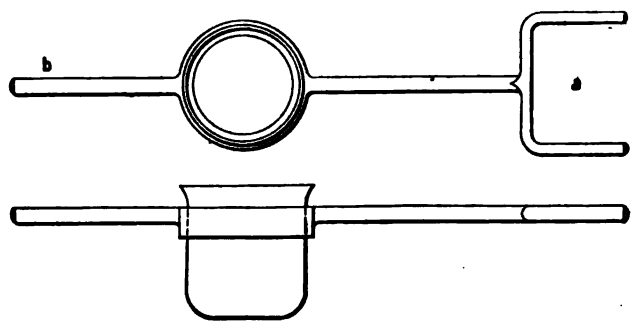


Fig. 37.

interior of the ladle is then daubed to a thickness of from 1 to 2 inches. The daubing is thicker at the bottom than at the top, and should be spread smoothly. After the daubing a wood fire is built within the ladle. This serves to dry the clay. If it were allowed to remain damp the steam formed by the molten iron would blow the latter out of the ladle. Many serious accidents have been caused in this manner. The ladles that can be carried by hand are usually held in a frame as shown in Fig. 37. The ladle thus hung is usually carried by three men. One takes hold of the two handles of the fork at *a*. The other two take hold of the single bar at *b*. The object of this arrangement is to give the moulder, who carries at *a*, complete control of tilting the ladle and pouring of the metal. The lengths of the arms are proportioned to put approximately the same weight on each man. At the same time the moulder carries more than one-third of the weight because he is in a better position than the others to do so. Ladles small enough to be carried by one man have a single handle as at *b*.

Grades of Iron. The grade of iron for a particular class depends upon the intended use of the casting. The natural

grades of pig iron are varied by mixing with each other and by the addition of scrap. The pig irons are placed in one of three grades known as No. 1, No. 2 and No. 3. There is no absolute distinction between them for they merge into each other by imperceptible gradations. The metal, when cast, contains from three to five per cent. of carbon, besides such elements as silicon, sulphur, phosphorus and manganese. In some cases it also contains arsenic, copper, etc. Carbon is the distinguishing element of pig iron. It occurs in two forms; the combined, and graphitic or uncombined. The difference in the grades of iron depends upon the relative proportions of these two forms of carbon. A large percentage of the carbon in the soft, gray irons is in the uncombined form. In the hard, white irons this carbon is almost wholly combined. The carbon contained in cast iron never exceeds five per cent.

No. 1 iron contains the largest amount of uncombined carbon. It is of a dark bluish gray when broken. The fracture also shows numerous graphitic scales. This iron is weak and has a low tensile strength. It is used for light castings intended for ornamental work. Sometimes this iron contains so much uncombined carbon that, when melted, *kish* appears on the surface. *Kish* is a carburet of iron, which, when cold, appears in bright shining scales. In the ladle, as a liquid, it floats upon the surface. It possesses most of the properties of graphite but contains less carbon. When kish appears the iron is unfit for use.

No. 2 iron contains a smaller amount of uncombined and more combined carbon. The fracture is more regular than that of No. 1. The crystals are smaller and the color a lighter gray. It is harder and stronger than No. 1, and is used for the general run of foundry work.

No. 3 iron contains less uncombined and more combined carbon than either No. 1 or No. 2. The fracture is regular. The crystals are still smaller and the color still lighter than No 2. It is also more dense and stronger than No. 2. It is suitable for use in heavy work. When melted it is less fluid than either of the other two. It is too hard to be readily worked in a machine.

There are still higher numbers. These are known as forge irons and are suited only for puddling.

The effect of the other impurities, such as silicon, sulphur, phosphorus and manganese is also very marked. These always exist in much smaller quantities than carbon. In Lake Superior charcoal iron there will usually be found about 2.25 per cent. of silicon; .03 per cent. of sulphur; .10 per cent. of phosphorus and from .15 to .18 per cent. of manganese. When silicon occurs above a certain per cent. the iron is weakened. If this proportion is large the iron is made hard and brittle. Small quantities of sulphur strengthen; phosphorus weakens iron, and makes it more fluid when melted. Manganese gives iron a white appearance and renders it more brittle. Where iron is to be cast in a chill, as explained later, the addition of powdered manganese tends to increase the depth of the chill.

Any degree of hardness and strength may be obtained by mixing the above-described irons in suitable proportions. Where iron is to be subjected to blows as in heads and anvils of steam hammers, there should be a preponderance of No. 3. For steam engine cylinders and all castings to be machine finished, where the surface must be hard and smooth there should be a preponderance of No. 2. The iron selected should be compact and free from an excess of uncombined carbon. It may be hardened by mixing a little scrap with it.

Remelting iron tends to harden it, to drive out the uncombined carbon and to give it the characteristics of No. 3. When iron is said to be a good *scrap carrier*, it is meant that it contains a considerable percentage of uncombined carbon. This excess of uncombined carbon makes up for the deficiency of the same in the scrap. The casting produced by the mixture has the characteristics of castings made from No. 2 iron of good quality, except that it is not as strong.

The tensile strength of cast iron varies from 20,000 pounds to 40,000 pounds per square inch of section.

Cooling of Castings. As stated in "Pattern Making," it is very desirable that a casting should be made as nearly of a uniform thickness as possible. Where the thickness of the metal varies, the thin portions cool more quickly than the thick. Internal stresses are thus set up in the metal which may cause a fracture. If the casting is not actually broken it is strained so that it is not

strong enough to stand the load which it was calculated to bear. This is shown in Fig. 38 in an exaggerated form. The thin rim of the pulley cools first. It becomes hard, solid and fixed while the heavy spokes are yet at a high temperature. As the spokes cool they contract. This contraction of the spokes pulls the rim toward the center and probably results in a fracture.

It is not always possible or desirable, however, to make castings of a uniform thickness. Where the thickness does vary the cooling may be made uniform. This is done by knocking the sand off from the casting and exposing the thick parts to the air while the thin parts are kept covered by the sand. The heat is, therefore, retained in the latter and its radiation checked, while the radiation is facilitated in the thick portions.

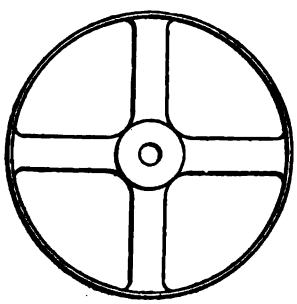


Fig. 38.

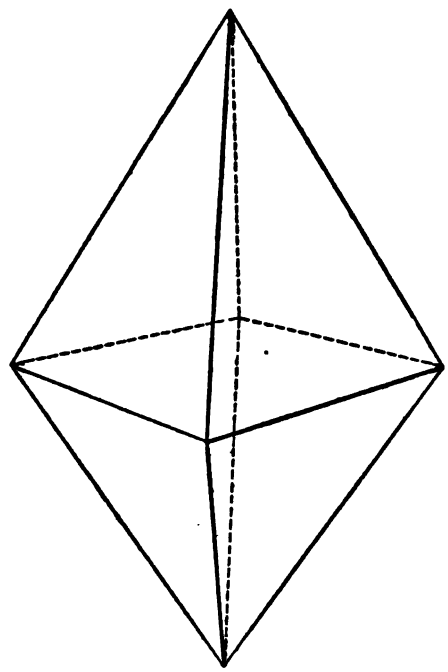


Fig. 39.

Effect of Shape on Castings. In "Pattern Making," the necessity of fillets in all corners was stated. The reason for this is that any sudden variation of form tends to weaken a casting whether the thickness varies at that point or not. When cast iron changes from the liquid to the solid state it crystallizes. The crystals thus formed are either of a right square-based octahedral form as in Fig. 39 or that of a regular octahedral as in Fig. 40. These crystals always arrange themselves with their axes perpendicular to the cooling surface. When the

casting cools slowly the crystals are larger than when it cools rapidly. The larger the crystals the softer the metal. Fig. 41 shows the effect of cooling when the corners are rounded, also when they are sharp. It will be seen from this representation of the arrangement of the crystals when cooling, that there is a line connecting the two sharp corners *a* and *b* where their axes lie at right angles to each other. The casting will be weak along this line. On the other side where the two changes of direction, *c* and *d*, are rounded there is no sudden change of direction in the line of axes of the crystals and the casting retains nearly its full strength. A fillet in the corner at *a* would tend to relieve the stress. Fillets should therefore always be used in such places. If it is necessary that the finished work should have a square corner or a sharp angle, let it be made in the machine shop by cutting away the excess of metal left on the casting.

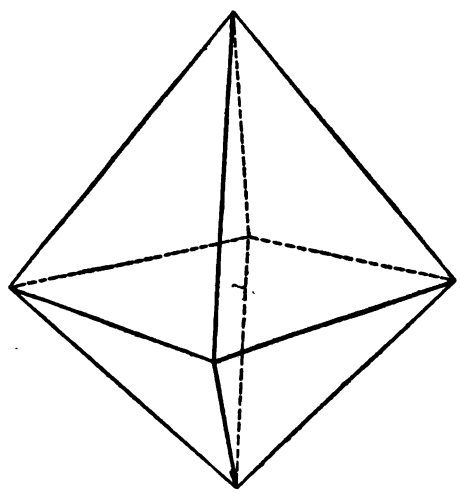


Fig. 40.

Cleaning Castings. After the castings have been poured the sand is usually shaken off from the heavier parts so as to produce an even cooling as already stated. The pouring is usually done at the close of a day's work. When the sand is shaken off, the sprues are broken from the casting by the blow of a hammer. The cleaning is done the next morning. This consists in removing the sand that may adhere to the surface of the castings, and taking the cores from the inside. There are three methods of removing the sand: by rattling, by brushing and by the sand blast. The first is used for small castings. They are put into a cylindrical shell, which is slowly revolved. The castings are thus tumbled over each other. As they rub and strike together the sand is removed and the surface of the castings made smooth and bright.

The brush is made of strong steel bristles. These remove the sand from the surface of the casting. The brushes may be used by hand or be driven by power. This is the most common method of cleaning castings.

The sand blast is used upon heavy castings. It consists of cutting off the adhering sand by a stream of sand impelled by a current of air. Care must be exercised in using the sand blast as the sand has very great abrasive power. If allowed to strike

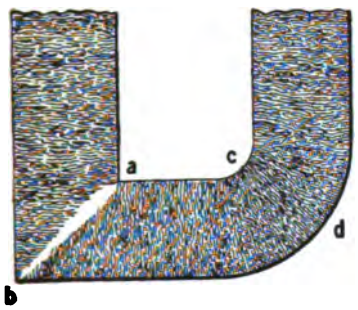


Fig. 41.

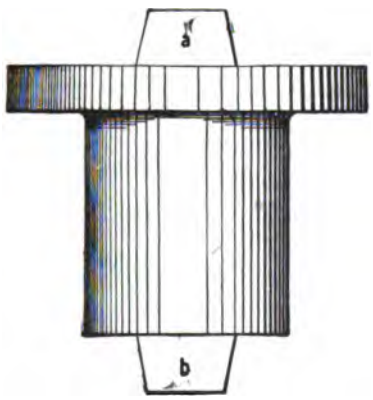


Fig. 42.

against the metal of the casting it will cut it away, and groove it deeply.

The sprues that are knocked off from the castings are usually thrown into the rattler with the shot and fine iron left in the debris from dumping the cupola. After these have been cleaned they are again thrown into the cupola and melted as scrap.

Shot is the term applied to the small pieces of metal found in the cupola dump. They are usually hard and are similar to a high grade of No. 3 iron. *Scrap* is the metal that is thrown aside and is useless except it be re-melted and re-worked.

Moulding a Gland with Core. It was stated in "Pattern Making" that a gland could be moulded so as to make its own core. This is illustrated by Fig. 23 as described in connection with Fig. 28. It may also be moulded with a vertical or a horizontal core. When moulding with a vertical core the work of ramming the drag is done in precisely the same way as when the pattern made its own core as in Fig. 23. When the drag is

turned, however, the loose core print *a* (Fig. 42) is put in position and the cope sand rammed over it. Parting sand is always used between the cope and the drag.

The mould thus made is shown in section in Fig. 43. After the pattern has been removed from the sand and the mould sleeked and finished, the core is set. The core is made, as described, of a uniform diameter from end to end. It is then cut to the proper length so that it will exactly reach from the bottom of the print *b* in the drag to the top of the print *a* in the cope. It is filed to the same bevel as the prints. The drag end is set in position, and the upper end adjusted with inside calipers so that it stands exactly central with the mould. The cope is then put on. When this is done the moulder usually stoops and looks up at the under surface of the cope, while two helpers lower it into position. This work must be carefully done and particular attention paid to having the core enter exactly into the print. If it does not it will tear away a portion of the sand which will fall into the mould and spoil the casting. The mould as thus made consists of the gate *d*, the space *c c* and the core *a b*. The line A B is the parting line.

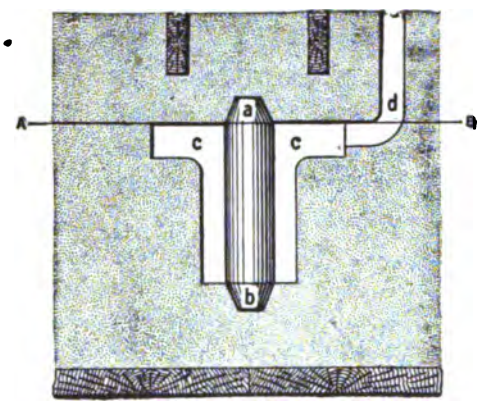


Fig. 43.

When the pattern is to be moulded horizontally the work is done in precisely the same way. The pattern is split along the center line with core prints on the ends as shown in Fig. 44. The construction of this pattern is described in "Pattern Making" on page 35. The half of the pattern *without* the dowel pins is laid upon the moulding board and the drag is rammed. After this is done the other half is put in position and the cope rammed. The core is then cut to length, put in position and the mould closed, as shown in Fig. 45. It then consists as before of a gate (not shown), the space *c c*, and the core *a b*. A B is again the parting line.

Use of Chaplets. Sometimes when the core is very long, it

must be held in position by other means than that of the prints alone. It is well known that the core is lighter than the iron. It, therefore, has a tendency to float upon the latter. In the case of a pipe casting as shown in Fig. 46, if the iron were to be poured into the mould, while the core was carried by the prints alone, the core would be bent upward at the center. This would weaken the pipe by making the metal much thinner upon one side than upon the other. *Chaplets* are used in order to prevent this. The usual form of chaplet is shown in Fig. 47 and they are also shown at *a a* Fig. 46. They are made of an iron rod varying from $\frac{1}{4}$ inch to $1\frac{1}{8}$ inches in diameter. The diameter to be used depends upon the thickness of metal through which it is to pass. The smallest size is suitable for a pipe whose metal is about $\frac{1}{2}$ inch thick. The largest size should only be used where the thickness is about $3\frac{1}{2}$ inches. Intermediate sizes in proportion. Chaplets are also made blunt at each end without the head. Where the core is very long, or the metal is run in from one side in such a way that its momentum is likely to displace the core, chaplets are set upon all four sides of the core. To set the chaplets, have the mould open. Push the sharp end of the chaplet into the sand until the head stands out the exact thickness of the metal to be cast. This is done in both the cope and drag. If this is done the heads of the chaplets will come to an exact bearing against the core as shown in Fig. 46. They will thus hold the

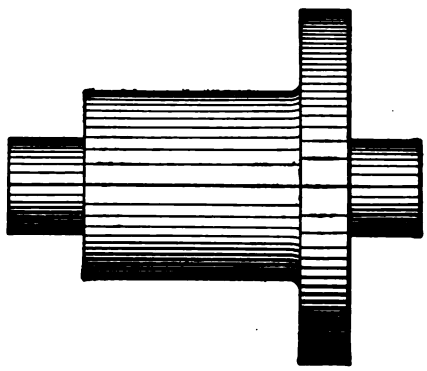


Fig. 44.

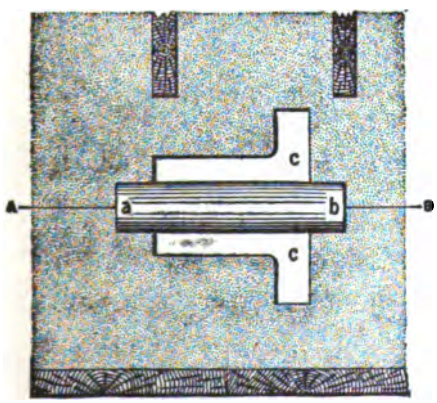


Fig. 45.

core in position while the iron is being poured and is cooling. When the casting is removed from the sand the chaplets will be found imbedded in the iron. The projecting parts, which were imbedded in the sand of the mould are cut off and the balance allowed to remain.

Chaplets are also made in the form of studs as shown in Fig. 48. When in this shape they simply rest upon the core or sand

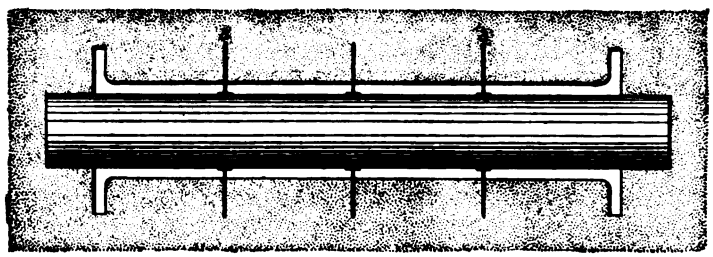


Fig. 46.

and are entirely imbedded in the metal of the casting. They are not adjustable. Each one is suited to a single thickness of metal. They are used where many castings of the same thickness are used. Where these thicknesses vary, the chaplet shown in Fig. 47 is usually the only one used.

The use of rusty chaplets should always be avoided. The hot metal striking the rust decomposes it. This forms a gas that suddenly expands and is likely to cause an explosion. The result may be the destruction of the mould. The force of such an explosion may be sufficient to be felt for a distance of from six to eight feet.

Fig. 47.

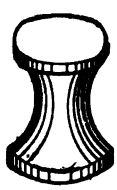


Fig. 48.

The forms of chaplets are not confined to the two shapes shown in Figs. 47 and 48. They may be of a great variety suited to the particular place in which they are to be set. They all belong, however, to one of the two types illustrated, that is, those held by being partly pushed into the sand and those resting on the cores or mould.

Gaggers. Sometimes the cope must carry a great depth of sand. In the flasks thus far described, the sand is lifted in the

cope by virtue of the adhesion of its grains to each other and to the sides and bars of the cope. This adhesion to the bars of the cope may be increased by giving the whole of the interior a bath of clay water. This should always be done when there is a considerable depth of sand to be lifted. The sand may be still more firmly held by the use of *soldiers*. These are usually made of short pieces of rough pine about one-half inch square. They are dipped in clay water and arranged in rows along the face of the bars. They merely serve to increase the surface to which the sand may adhere. They are, themselves, held to the bars by the clay water which thus forms a sort of paste. When the depth of sand is too great to be thus lifted *gaggers* are used. A *gagger* is

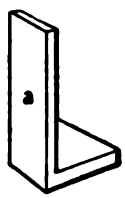


Fig. 49.

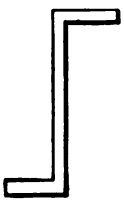


Fig. 50.

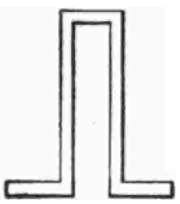


Fig. 51.

a piece of bent iron suspended at one end from the bars of the cope and carrying the sand on a projection formed at the other. Some common forms are shown in Figs. 49, 50 and 51. Fig. 49 is a simple form where the back *a* is stuck to the bar of the cope with clay water. Fig. 50 is a gagger that may be hung from the side of the cope or one side of a bar. The form shown in Fig. 51 is intended to straddle the bar and give support to the sand upon both sides.

Follow Boards. In Fig. 58 of "Pattern Making" a wheel pattern was shown that could not be drawn from the sand. In Fig. 44 the round pattern is made in two parts. Where the pattern is small this is frequently undesirable. Where there are only a few pieces to be made, the method described on page 32 of "Pattern Making" may be followed. When many castings are to be poured from one pattern a follow board should be used. If the pattern is ornamented or is of complicated shape, the making of a wooden follow board is very expensive. The moulder can make a follow board very cheaply as follows: Have a frame made

to fit over the frame of a cope as in Fig. 52. The frame so made to be one-half the thickness of the pattern, as in B. This is set in position beneath the cope and set on the moulding board. The cope is then rammed with sand as directed for the ordinary drag. The sand used is, however, to be especially prepared. Take ordinary new moulding sand and dry it perfectly. Then mix it with boiled linseed oil until it is nearly the same consistency or a little more soft than when mixed for moulding. Ram the cope A and frame B with this sand. Turn over and remove the frame B. Cut away all the sand remaining above the parting line C D and sleek off the surface of the same until it is made as smooth as possible. This leaves the pattern half imbedded in

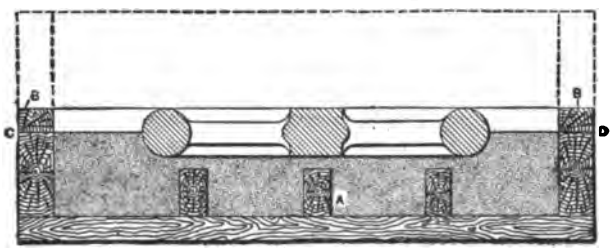


Fig. 52.

the sand of the cope A. Draw the pattern and finish the mould. The sand thus mixed with linseed oil will become as hard as a board. When dry it will form a perfect and serviceable follow board.

The method of using the follow board is to lay it face upward on the floor as shown in Fig. 52. Put the pattern in position and the drag upon the cope as shown. The drag, of course, rests upon the cope at the parting line C D. The frame B is not used. Ram the drag as described for ordinary work; turn the whole; remove the follow board; put on the cope and ram as in the case of simple or two-part patterns.

Three-Part Flasks. The greater portion of all moulding can be done with flasks consisting of a cope and drag as described. These are called *two-part flasks*. Sometimes, however, a casting is required of such shape that the pattern cannot be made of two pieces and drawn out of the sand of the cope and drag. When this occurs flasks of three, four or more parts are used. Fig. 53

illustrates the use of a three-part flask for the moulding of a flanged pulley. The pattern is made in two parts separated along the dotted line E F. It is evident that it could not be drawn from the sand if rammed in a two-part flask. The parting line would then be on the line E F. The flanges would be buried in the sand and could not be drawn. The use of a three-part flask makes the moulding possible. One half the pattern C′ E F D′ is laid upon the moulding board. The drag is set over it but raised by a frame the height D G. The sand is then rammed and the drag turned. The frame used for raising the drag is removed and the sand cut away and sleeked down to the parting lines C C′ and D D′. The middle section or *cheek* of the

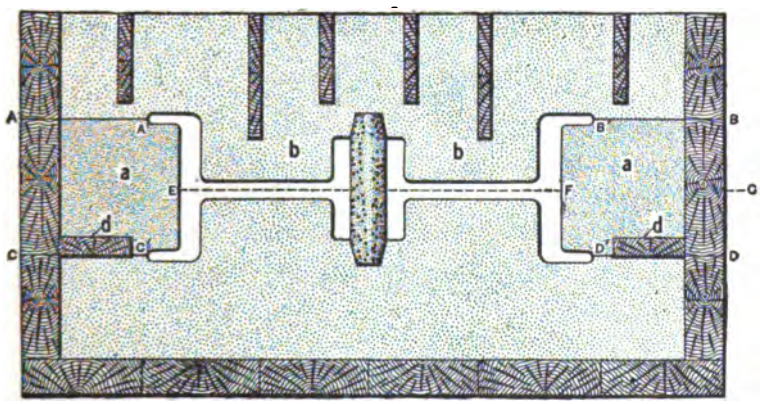


Fig. 53.

flask A C, B D is then put on the drag, the other half of the pattern set on its mate and the sand rammed outside the pattern in the spaces *a a*. This sand is sleeked off on the parting lines A A′ and B B′. The cope is then put on and rammed. The sand of the cope fills in the hollow *b b* on top of the pattern. The cope is then lifted off leaving the pattern in the sand. In drawing the pattern its upper half is first drawn out of the sand of the middle section; the middle section or *cheek* is then lifted from the pattern, and the bottom half is finally drawn from the sand of the drag. In lifting the middle section from the pattern, the latter should be gently rapped. Other and more complicated patterns may require the use of flasks of a greater number of parts,

but the principle upon which they are made and used is the same as that here given. The middle sections are provided with bars in the same way as the cope or better with the lifting plates *d d*. Usually flasks are especially fitted for this work. The bars should be so arranged as to conform to the contour of the pattern in order that the sand may be firmly held. Gaggers should always be used where needed.

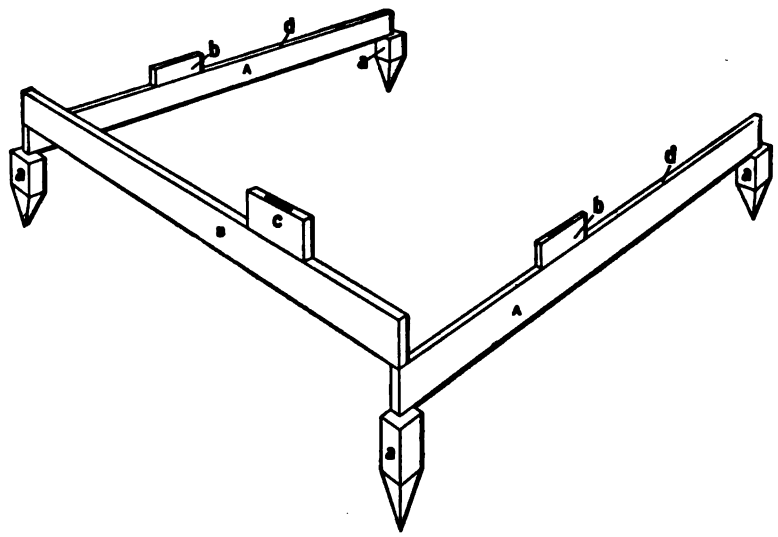


Fig. 54.

Open Sand Moulding. While it is the general practice to use flasks and patterns for the purpose of making moulds, it is sometimes possible to do the work without either or with only one. Where flasks are not used the mould is prepared in the sand forming the floor of the foundry. This work is usually confined to flat plates where the upper surface is large and smooth. As an example of this class of work, take a rubbing plate 6 feet square and 6 inches thick. This will weigh a little more than four tons. A place on the floor is selected that can be reached by a crane. The floor is first rammed hard and evenly over a surface of about 8½ feet square. The ramming is done at a level of about 6 inches below the floor surface in a hole excavated for the purpose. The bed must then be leveled over its whole area. This is done by setting straight edges in the sand 8 feet apart. The straight

edges are to be set perfectly level and of the same height. It is done with a spirit level as shown. The four stakes *a a a a* (Fig. 54) are driven into the ground at the proper distances as shown. Upon these the straight edges A A are leveled by spirit levels *b b*. They are, in turn, brought to the same height by the spirit level set on the straight edge B. When the two upper edges *d d* of the straight edges A A are adjusted, the floor is scraped off with the straight edge B. It is then sleeked smooth and the pattern laid on the same.

In this case the pattern may be a square frame as shown in

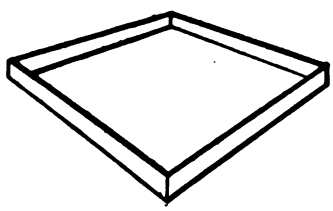


Fig. 55.

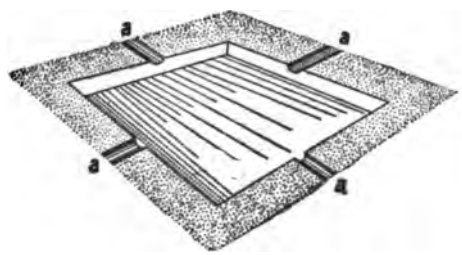


Fig. 56.

Fig. 55. The sand is then rammed about the outside of the pattern, the gates cut and the pattern drawn. This leaves an open mould as shown in Fig. 56. In pouring, the metal must not be run directly into the mould. The fall from the ladle would cut away the sand. It is therefore poured into basins and allowed to flow into the mould through the gates *a a* cut in the sand at the sides.

Dry Sand Moulding is frequently done in connection with green sand. It is employed where a casting is of a complicated design. The method pursued is to make a partial pattern with a core print; then make a flask to fit this print and in it mould the balance of the pattern, using dry instead of green sand. This mould is then baked in the same manner as an ordinary core which is set in the print formed by the main pattern.

Sometimes the whole mould is made of dry sand. This is frequently done in the case of cylinders for steam engines. Let us consider such an example. The cylinder to be moulded is shown in side and end elevation in Fig. 57. The method of

moulding is shown in Fig. 58. The actual moulding is very similar to that of green sand work. The pattern is made in two parts. The part including the steam chest is moulded in the drag. It has core prints to correspond to the cores *a a*. These cores are made in a special box which forms at the same time the flange of the steam chest. This half of the cylinder pattern also has core prints *b*, *b*, *c* for the port cores. The pattern is moulded in the ordinary way; first the drag and then the cope. The cores *a a* and those for the steam and exhaust ports are made and dried as explained in "Pattern Making," page 56. As the core *a a* has an overhang which forms the flange of the steam chest and as that overhang is subjected to the upward pressure of metal, it is tied to the main body of the core by double headed chaplets *f f*. The

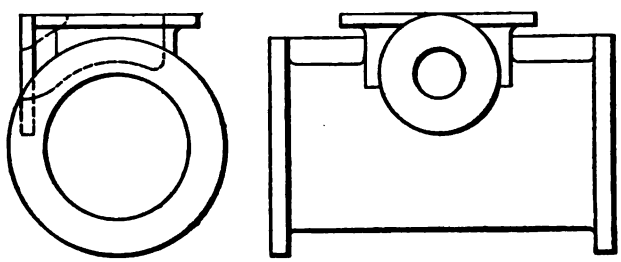


Fig. 57.

cores *d d* and *g*, forming the ports are also subjected to an upward pressure. They are, therefore, held down by bolts passing through the drag and plates on the bottom. As the cores *d d* are light and easily displaced by the flow of metal, they are held firmly against the center core by the chaplets *e e*. In this case the center core *h* is carried out through the side of the flask. This assists in carrying off the gases that are formed as it is not a solid core but is built upon a pipe as will be described later. This pipe has numerous holes so that it forms a flue in the center of the mass for the escape of gas. In making large dry sand moulds of this sort, the sand is well vented before being dried. Sometimes short lengths of perforated pipe are built into the sand to facilitate this escape. The cope is rammed and set on the drag as in green sand, except that it is dried before being used.

Shrink Heads or Risers. In making large castings shrink

heads are put on the cope. These are in the form of gates and large pouring basins. When the mould is filled, the iron rises in these basins and forms a reserve. From this reserve metal is drawn to keep the mould filled as the metal shrinks away from its sides in cooling. It is necessary that the basin or riser shall be connected with the main body of the casting by a narrow neck, which may easily be broken away, without injury to the casting. As this neck will solidify before the heavier parts in the mould or the body of metal in the basin above, *feeding* is necessary. Feed-

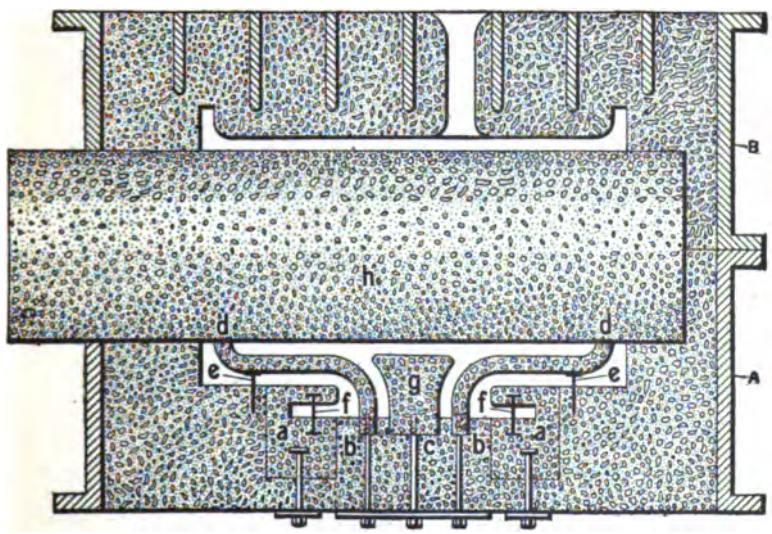


Fig. 58.

ing is accomplished by working an iron rod up and down through the neck while the metal is hardening. The method of doing this is shown in Fig. 59. In this figure *a* is the riser, *b* the mould; the rod is worked up and down in the neck connecting the two. When this is not done the upper portion of the casting is apt to be spongy and unsound.

Risers are also used for *pressure feeding*. To accomplish this comparatively small gates for filling the mould are used. These gates solidify as soon as the mould is filled. The risers which are placed on the heavy portion of the mould are then filled with metal. These have a head or depth of metal considerably greater

than that of the original gate. By having two such risers and pouring the metal into them alternately, that in the mould is kept in circulation for the longest time possible.

Core for Cylinder Jacket. The making and holding of the core that forms the steam jacket of a cylinder is an operation requiring great care. It can be made of loam or dry sand. It must be made about a cage, formed of rods and pipes. The jacket is usually cast with one end closed and four vent holes at the other. The diameter of the vent holes is equal to the thickness

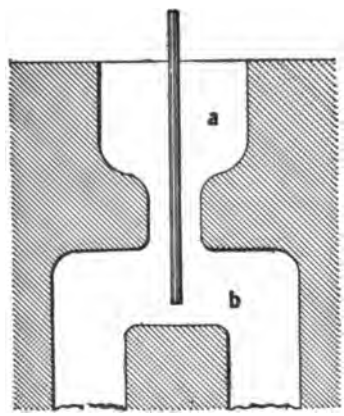


Fig. 59.

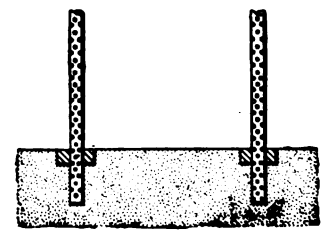


Fig. 60.

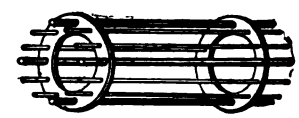


Fig. 61.

of the core. They are spaced at equal distances about the circle. The cage may be made by casting the rods and pipes inside of rings. The easiest method of casting the rings is to set the pipes and rods in an open sand mould and pour the metal around them as in Fig. 60. Reverse for the other end. The cage as finally made is shown in Fig. 61. The pipes are to be perforated for the escape of the gases. The dry sand is built about this cage covering rings, pipes and rods with the exception of one end of the pipes. These project from the core. The core, as thus made, is a hollow cylinder whose diameter and length corresponds to that of the jacket. This core is held in position by studs and chaplets. Fig. 62 shows the method of setting the core which is shown at A. It is supported by the chaplets *a a*, which are spaced at an angle of 120° around the circumference. Therefore those supporting the core do not appear in the section. The rear end of the core is

steadied by the studs *b b b*, which pass through the dry sand of the mould and are steadied by the wedges. The upper and lower wedges are reached by pockets left in the mould. The center one can be reached at the parting. At the other end the pipes are protected by the cores *d d d*. These cores also make the holes

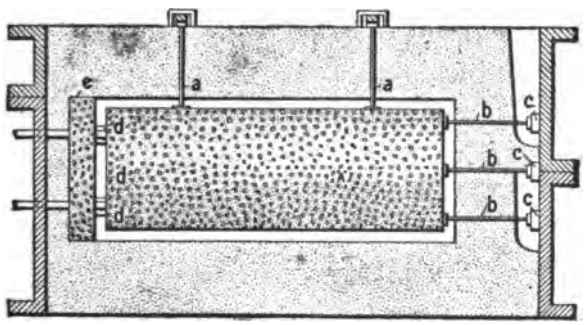


Fig. 62.

in the jacket end through which it is cleaned. The end face of the jacket mould is formed by the core *e*. This core is made in sections so that it can be placed about the rods when the core is in position and held by the studs. The method of cutting these sections is shown in Fig. 63. The mould is now ready for pouring. When the metal is cooled the cage of the jacket core will remain inside the casting. It is removed by inserting a cold chisel through the vent holes, breaking the rings into small pieces and withdrawing them through the holes. The rods are buried in the sand of the core which must, of course, be removed before any of the iron work can be taken out.

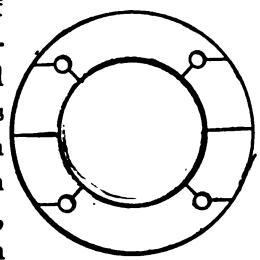


Fig. 63.

Moulding Square Columns. Square columns used in structural work are now common products of most foundries. They are invariably hollow. The exterior is usually plain though sometimes ornamented with simple devices, such as panels. The cores may be a combination of dry and green sand or dry sand alone according to the character of the work. They are of the combination type when there are holes through the side, where the green sand may be supported. They are of dry sand when the sides of

the casting are solid and the core can be supported at the ends only. The first type of column is shown in Fig. 65, and the second in Fig. 64. Where there are holes as shown in Fig. 65, the core is rammed in position. The pattern may consist of a hollow square box of any convenient length, provided only that it is longer than the column to be made. The flanges may be fastened to the pattern at the points which limit the length of the casting. These flanges should be thick enough to provide both for the thickness of the metal in the casting and the core prints. First ram and level the bed on which to lay the pattern. Then put on the drag, which is formed of loose sides and ends, held by cross bars. It must be long enough to hold the casting, but may permit the pattern to project through the ends. Ram the sides between the pattern and drag. Then set on the cope and ram that. For convenience of adjustment the cope had best be hinged to the drag. Turn back the cope and draw the pattern. Now place "false" side pieces in the mould. These are merely boards with drawing strips let into them and reaching to the top of the core. Their thickness is equal to that of the casting. Now place the false core bottom in the mould. This consists of a set of rectangular dry sand cores with projections on the under sides corresponding to the holes *a a* in the side of the casting. Next set the core bar in position. This is best made of a light I beam with holes drilled through the web. It should occupy the position in

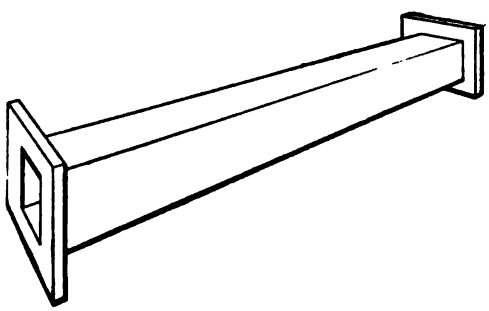


Fig. 64.

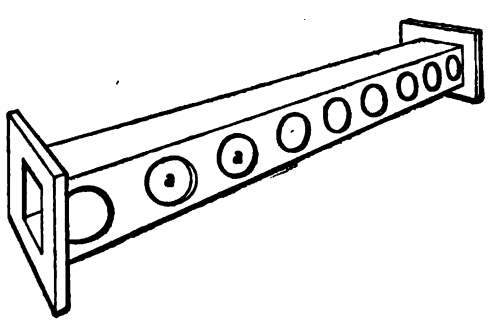


Fig. 65.

the mould as shown in Fig. 66. The I beam extends beyond the limits of the cope and is held down by driving wedges between the top flange and the end bars of the cope. Before this is done the core is rammed with green sand. The vent wires *a a a a* are laid in. If the core is much wider than the flanges of the I beams, bars *b b* are put through the holes in the web to hold down the sand. When the core has been rammed it is swept and sleeked down flush with the top of the false side pieces which rise to the points *c c* as indicated by the dotted lines. When this is done the false side pieces are withdrawn, the cope lowered to position and the I beam wedged down as directed. The metal, when poured, meets a core of dry sand *d* at the bottom of the mould with green sand above.

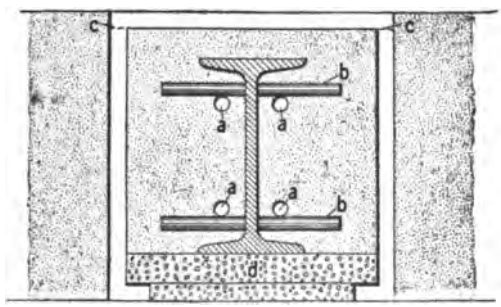


Fig. 66.

When the four sides of the casting are to be solid as shown in Fig. 64 dry sand or loam cores are ordinarily used. These are made over hollow iron cores which are coated with dry sand or loam. The iron cores are perforated with a large number of holes, which permit the gases formed to escape through the interior.

Moulding Round Columns. Round columns are usually moulded from a split pattern which is constructed as described in connection with Fig. 66 of "Pattern Making." The pattern is made of the maximum length of column to be cast. Loose flanges are used to limit the length of the pattern. The cope and drag have semi-circular holes or spaces cut out of their respective connecting edges to allow the excess length of pattern to project beyond them. As round columns are almost always solid in the shell, dry sand or loam cores are used. These cores are built about a perforated iron pipe which serves to carry off the gases.

Gear Moulding may be done from either full or partial patterns. When done with full patterns, the work is identical with

that of the simpler castings that have been so fully described. They are laid on the moulding board and the drag and cope rammed in the regular sequence.

Gear Moulding with Partial Patterns. Owing to the great expense attendant upon the making of large gear patterns, such work is usually done with sectional or partial patterns. These usually consist of a section of the rim to which a limited number of teeth are attached. This pattern is placed in successive positions about the mould and the teeth rammed separately. It is held by a spindle set and held vertically at the center of the mould.

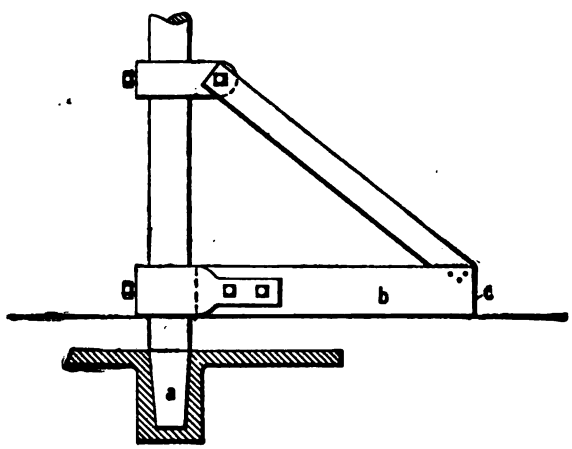


Fig. 67.

This spindle is turned to any convenient diameter and is provided with two sleeves that slide freely over it and to which the pattern is attached. For moulding a spur gear the pattern should have three or more teeth whose length is equal to those of the casting. The spindle is set in a step as shown at *a*, Fig. 67. This step must be of sufficient length to hold the spindle in a vertica. position. The length depends upon the overhang of the arm *b*. The arm consists of a board bolted to one of the sleeves fitting over the spindle and braced to the other. The step is set in the sand of the floor and is held by radial arms. It must be sunk to a depth of from 6 to 12 inches more than the length of the tooth. This depth is dependent upon the weight of the gear to be moulded. The sand is then rammed into a hard bed and the floor swept off

level with the sweep as shown in Fig. 67. Next remove the sweep and slip a washer over the spindle. This washer must be of the same diameter as the hub and of a thickness equal to the projection of the latter beyond the rim. Set the cope in position and stake it to the floor. These stakes are to be so driven that they will serve as guides by which the cope may again be lowered to exactly the same position after the mould is completed. After the cope has been removed, dig a hole about the spindle and imbed the washer in the sand again to the proper depth in order to form the other end of the hub. This adjustment may best be made by marking the spindle when the washer is in the first position, and making the second setting by measurement The bottom bed is now swept. This is done by lowering the sweep so that its bottom comes against the upper face of the washer. This floor is swept so that it extends several inches beyond the outer ends of the teeth. The sectional pattern is now attached to the spindle. This is accomplished by having a frame which, when slipped over the spindle will set the teeth at the proper distance from the center. The pattern should be set and gently pressed down upon the bed so as to form a faint imprint in the same. Then raise and swing it around until the tooth at one end of the segment exactly corresponds and fits into the print made by the tooth at the other end. Press it down upon the bed again and make another set of marks. Repeat the process until the entire circle has been completed. The teeth should exactly correspond and be of the same pitch without a break. If they join accurately at the end of the circle the pattern is in correct adjustment. If they do not, an error has been made and the work must be done again until the prints are uniform. When this is done the ramming may begin.

Set the pattern in the prints that have been made and ram the sand about the outside. Boards may be temporarily set in the sand to protect the ends. When the section has been rammed draw the pattern by raising it with its attachment to the spindle and set it again in the prints beyond. Allow the rear tooth of the pattern to rest in the mould already made about the tooth previously in front. Repeat the process until all of the teeth of the circle have been made. Remove the pattern, and dress the sand forming the teeth.

The arms of such gears are usually made with dry sand cores. The pattern to which the teeth are attached should have a length that will reach from one core to another whether the teeth do or not. Raise the sweep and set the cores in position as shown in Fig. 68. Set the pattern which has the section of rim, so as to

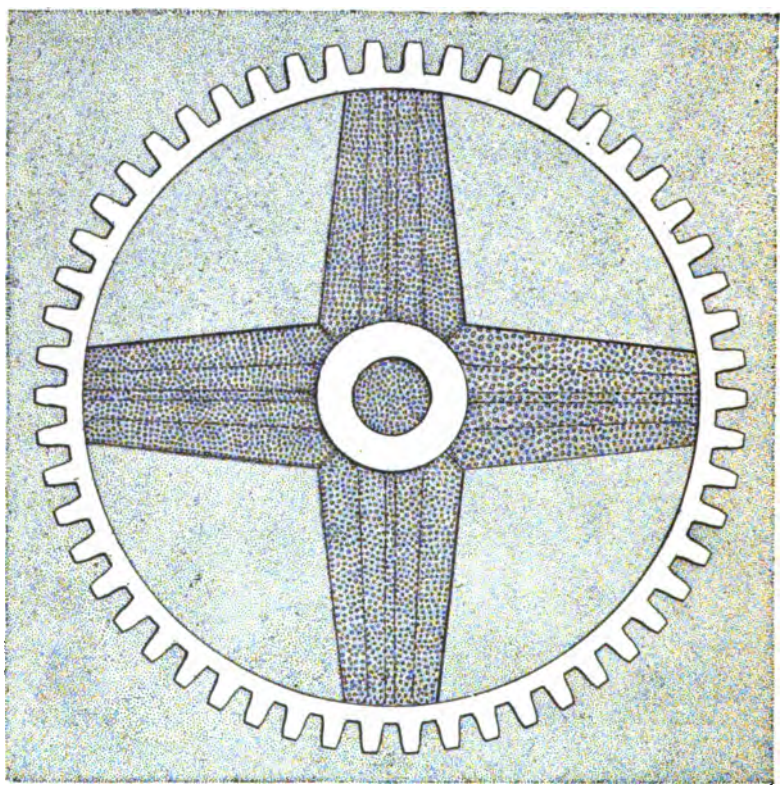


Fig. 68.

make a connection from the outer end of one core to the next. Ram the sand in between the pattern and the cores and sweep the former level with the top of the latter. Sleek this surface off and finish. Then withdraw the pattern and shift to the next section, and so continue until the mould is completed. The dry-sand cores for the arms are made in boxes and baked as already described. Now withdraw the spindle and washer and pack the hole left by

FINISHING MOULDS FOR A LOCOMOTIVE DRIVING WHEEL

the former with green sand up to a point where it is convenient to form a rest for the center core. Set this core, and the mould is ready for the closing of the cope.

Moulding Pulleys. As already stated in "Pattern Making" on page 42, pulley patterns in a complete state are rarely used. Instead a ring, a pattern for the spokes, and loose hubs are used for making all widths of face for a given diameter. The ring is of cast iron turned smooth. It has holes drilled near the edges in which lifting hooks may be placed for drawing. If one-half the face of the pulley is to be less than the total width of the ring the latter is first set on the moulding board as for ordinary patterns.

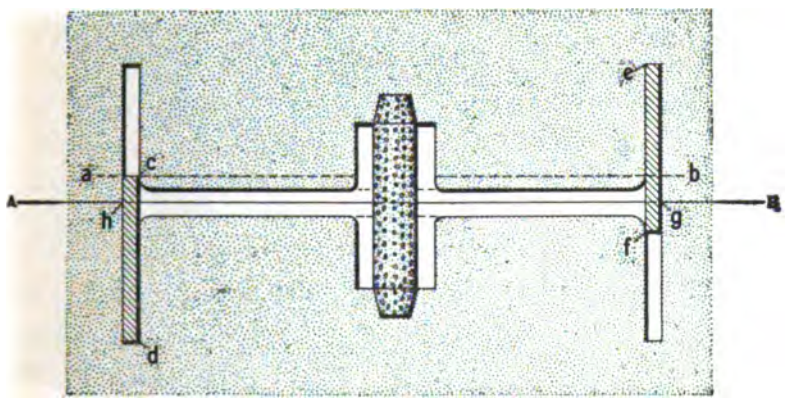


Fig. 69.

This is illustrated in Fig. 69 where the dotted line *a b* represents the face of the moulding board. The amount by which the total width of the pattern exceeds the half width of the pulley face is represented by the distance between the dotted line *a b* and the full line A B. The line A B will be the parting line between cope and drag. The drag is raised from the moulding board by a frame or wedges of this width. Ram some sand in the bottom and lay in the pattern for the spokes. This pattern is usually solid. It must be imbedded in the sand on the moulding board so that its center is exactly in line with the parting line A B. The hub with the core print is then put on and the sand of the drag rammed as in the case of any ordinary pattern. When the drag is turned the sand is cut away to the parting line. The surface of the parting

line is then sleeked off. This leaves the ring projecting above the surface of the parting line by the distance *c h* as shown by the hatched section of the pattern at the left of Fig. 69. The lifting hooks are then inserted in the ring and it is drawn out of the sand of the drag until it occupies the position *e f* as shown by the hatched section on the right of Fig. 69. The friction of the sand is depended upon to hold up the ring. If the depth *f g* is insufficient to do this, the ring is not drawn to the full height at first. After raising the ring the cope is put in position and rammed as usual. Great care must be taken that the rammer does not strike the ring. Before ramming, the top section of the hub is put on.

If the ring is not drawn to its full height at *e* for the first ramming of the cope, the sand of the latter is rammed about it, and the pattern raised again. The ring is sometimes moved four or five times before the full width of the face is made. After ramming in this way, the cope is lifted off and the ring usually comes with it in the sand. The cope is turned for finishing and the ring withdrawn. The hub and spoke patterns are removed in the ordinary manner. The mould is usually filled from the hub.

In case the width of the ring is less than half the width of the pulley face, the ring is drawn up in the ramming of the drag in the same manner as already described for the cope. When the drag is turned, it is drawn in the opposite direction as stated.

When the width of the ring is greater than the total width of the pulley face there is more difficulty. The mode of procedure for the ramming of the drag is the same as in the first instance. In ramming the cope, it is placed on and rammed nearly to the top of the ring. The sand is then cut away to such a level that the ring is just embedded in cope and drag by the width of the pulley face. The ring is then drawn out of the sand. The annular hole thus left in the sand of the cope is covered by a series of flat dry sand cores. When these are set the ramming of the cope is continued. After this has been done the cope is lifted and the spoke and hub patterns removed.

Spur gears with different lengths of teeth may be moulded in this same way from but one pattern by a partial withdrawal of the pattern and successive ramming.

Moulding Wheels. The moulding of fly-wheels may be done either with or without patterns. In case a pattern is used the work is done as already indicated for ordinary work. Where no pattern is used the sweep again comes into play. In this case, however, the outside face of the mould as well as the bed is swept. This leaves a cylindrical pit with a diameter equal to that of the wheel to be made and a depth equal to the face of the rim. The cores for the spokes are placed exactly as already described for gear wheels.

Large wheels are usually made in sections. This is done to avoid the dangers of internal stresses and the resultant cracking due to cooling. These sections may be cast from a pattern or swept as desired.

Broad faced pulleys of large diameter are also usually swept. In every instance the work may be done as already described for fly-wheels and gears.

Pipes are usually moulded on the side with a dry sand core as already described for columns. It is customary, however, in many foundries to turn the mould on end for pouring. When this is done a riser is located at the upper end into which the impurities of the iron and the washings from the core may rise as a scum. This insures a sounder casting than when cast on its side. All cast iron pipes that are to be subjected to an internal or external pressure should be cast on end.

Chilled Castings is a name applied to a class of casting wherein the metal has been suddenly cooled or chilled immediately upon pouring. The means usually adopted for chilling castings is to pour the metal against a piece of iron that forms a part of the mould. The effect of this sudden chilling is to produce great hardness on the face of the casting. The most common example of chilled castings is the cast iron car wheels that are used on all American railways. In this case the tread and flange are chilled. The *chill* is that portion of the mould which is made of iron against which the hot metal strikes. Chills for car wheels are made in several ways. The original form was a plain smooth ring that was turned to the contour of the tread and face of the flange. This ring was about 3 inches thick, in order that it might not itself become over heated. Of recent years the *contracting* chills

are used. These are of various forms. One is shown in Fig. 70. In this the chilling face *a* is divided into a large number of segments which are attached to the main ring *b* by narrow necks. The object of the contracting chill is to keep the metal of the chill and the casting in contact until the latter has cooled.

The molten metal heats and expands the common chill and at the same time the cooling casting contracts or becomes smaller. The result is that the time of actual contact is very brief and the casting is likely to become imperfect in shape when cold. With the contracting chill the face *a* with its neck is heated and

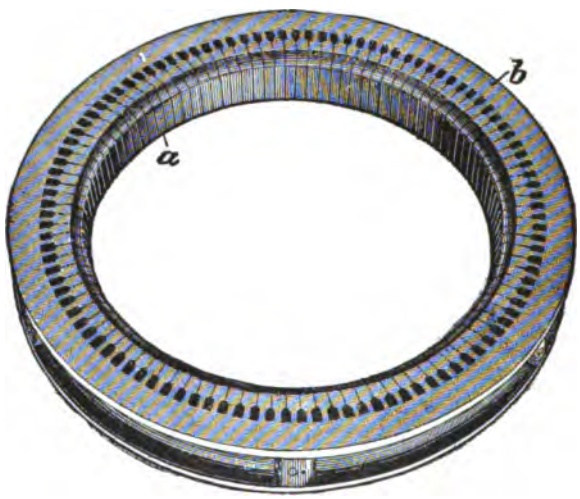


Fig. 70.

expanded by the molten metal. It is fastened at its outer end to the heavy solid ring *b*, which is too far away from the molten metal to become heated. As a result the face and neck are pushed toward the center by their expansion and the diameter or the chill is lessened. This type of chill, therefore, follows the shrinking casting and remains in contact with it until it is cold. Other types of contracting chills are simply plain rings of the original form, which have a stream of cold water circulated through them after the metal has been poured. Some of these are plain rings, in others the contracting necks are as in Fig. 70, with the outer ring *b*, through which the water is circulated.

The moulding of castings that are to be chilled is done in the same manner as ordinary castings. The chill is either set in position like a core or forms a part of the flask as in the case of a car wheel chill.

Chilled castings should be annealed before using. The sudden cooling of one part sets up internal stresses that will result in fracture unless relieved by annealing. The usual method of annealing car wheels is to remove the casting from the mould while it is still red hot. It is placed in a pit 7 or 8 feet deep and having a diameter a little larger than its own, with enough others to fill it. They are covered and then buried in ashes. Thus protected the wheels cool very slowly. The internal stresses are relieved because of the shape which the metal takes. This annealing usually takes about one week.

The depth of the chill, or the thickness of the exceedingly hard metal varies from $\frac{1}{16}$ to $\frac{5}{8}$ inch. It depends upon the character of the metal used, the heat at which it is poured, and the rapidity with which it is cooled. In car wheels the depth of the chill is about $\frac{3}{8}$ inch.

All irons are not suitable for the making of chilled castings. No. 1 and No. 2 iron that are rich, or comparatively so, in uncombined or graphitic carbon do not chill readily. The best chilled car wheels are made from the irons containing combined carbon. Salsbury and Lake Superior pig has, until recent years, been most extensively used for car wheel making. As these irons, especially when made in a charcoal furnace, are expensive, they are being supplanted by cheaper mixtures.

Loam. The composition and mixing of loam has already been described. Loam cores made over a perforated barrel or pipe have also been alluded to.

Loam Cores. Where the core is long and can best be supported at the ends only, loam cores are frequently used. They are also used where the core would be very large and heavy if made of dry sand. The advantages possessed by loam cores are that they are lighter, more cheaply made and offer better facilities for the escape of the gases than do the solid cores of dry sand. The method of making loam cores is very simple. A piece of pipe about three inches smaller in diameter than the outside diameter

of the core is selected to form the center. This pipe is perforated by a large number of holes. If the pipe is more than three or four inches in diameter, centers or trunnions are placed in the ends to serve as bearings. This pipe is then arranged to revolve freely as shown in Fig. 71. A crank handle is attached to the pipe by which it is turned. The pipe is first wound with hay rope having a diameter of from $\frac{3}{4}$ to 1 inch. Where only a small amount of hay rope is used it is either bought ready-made or is twisted by hand. In foundries where large quantities are used the rope is made in machines built especially for the purpose. The rope should be made of long wisps and tightly twisted. It is laid on

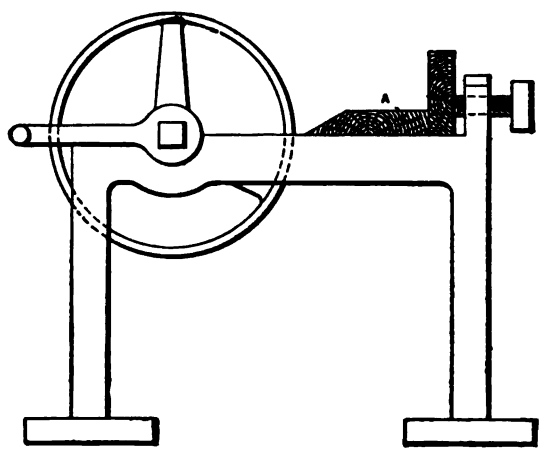


Fig. 71.

the pipe by fastening with a wire at one end and winding tightly to the other end where it is fastened in a similar manner. After the rope has been wound on and secured in position the loam is applied. This is done by means of an adjustable board A Fig. 71. The beveled edge of this board is set so that its distance from the center of the pipe is exactly equal to the radius of the core that is to be formed. The loam is then shoveled upon the board A and the pipe turned in the same direction as when the rope was being wound. The first coat of loam used should contain a considerable proportion of clay. This will make it tough and adhesive. The first coat must be well rubbed in and worked into all of the uneven places and

cavities. If this is not done the casting will be rough and lumpy. This work is done by hand as the barrel is being slowly turned. Too much care cannot be taken in this portion of the work. After the rope has been covered and the loam pressed into it as firmly as possible, take a small iron bar, $\frac{5}{8}$ or $\frac{1}{2}$ inch in diameter and press against the joints between the ropes, turning the barrel and working from end to end. When this is done, work in more loam and then press the whole down firmly with a block of wood while the pipe is being slowly turned. The second coat of loam which should be of such thickness as to leave about $\frac{3}{8}$ inch for the finishing coat is then put on. The second coat should be made very stiff. Unless this is done it will bag and make an uneven core. Sometimes it is advisable to so adjust the sweep board A that a smooth surface is given to the second coat. This facilitates the laying of the finishing coat. The barrel is usually placed in the oven and baked before the finishing coat is applied.

While it is still hot it should be removed from the oven and rubbed down. This is done by setting it in its bearings and pressing a brick against it, while it is being turned. This breaks the skin, roughens the surface and removes the smoke black.

The finishing coat should be put through a sieve of eight meshes to the inch and thoroughly mixed. Put enough on the sweep board A to finish the core. Before making an application of the loam, brush off the prepared surface and moisten slightly. When this has been done, let the barrel be turned slowly, and apply the loam with the hands. After one revolution make the loam thinner. The more rapidly the core is finished the better will be the results. Two revolutions of the barrel is better than a greater number. When the core has been built to size, move the loam back from the edge of the board A and then withdraw the board while the barrel is still in motion.

Rough places and lumps should be smoothed with a block of wood and not with a trowel. If the core is of large diameter, it should be turned until the loam has set in order to avoid a tendency to bag. The thickness of the loam to be put over the rope depends upon the thickness of the casting to be made around it. Castings 2 inches thick will need about 1 inch of loam. In such cases the pipe should be 4 inches smaller in diameter than the

finished core. As soon as the surface of the mould has become hard enough to absorb the blacking it should be applied. The best condition of mould or core for blacking is when it is just damp enough to soak up the material, and be ready for sleeking in five or six minutes thereafter. In sleeking a loam mould, press on gently with the tools. Too great a pressure closes the pores and tends to start the blacking from the surface of the mould. The less the sleeking the better. Rough places or marks left by sleeking can be smoothed by going over the surface with thin blacking applied with a camel's hair brush. After blacking, the core is again dried in the oven, when it will be ready for use.

The object of using hay rope about the pipe is two-fold: it serves as a convenient binder for the loam and by burning or disintegrating under the influence of heat, the pipe is loosened and easily withdrawn from the casting. If the loam is too thin, the rope will be entirely burned away. When this occurs, the loam is crushed in and the iron, in contracting, is apt to so pinch the pipe that it can only be removed with difficulty.

Loam Moulds may be made without any patterns, with partial patterns and with complete patterns. The first is only used where the casting is of the simplest form. The second is the common method of making loam moulds. The third is seldom used, since a complete pattern makes it possible to mould in green or dry sand, which is cheaper than the use of loam. Loam moulds are usually built of bricks over which a coating of loam is spread. The loam, that is spread on brick work, is of the same character as that already described for loam cores. It is applied and treated in practically the same manner. Loam moulds are usually employed where the casting is large; where only one of a kind is to be made, and where it would be expensive to provide a pattern. They are also used in emergencies where the casting can be made in loam more quickly than a pattern for dry or green sand moulding could be put together. The most frequent application of loam moulding is to be found in the making of large cylinders for steam engines.

Simple Cylinders. In the moulding of a simple cylinder like that shown in Fig. 72, the casting is made with a shrink-head as shown by the dotted lines at *a*. This is to receive the dirt and

washings from the mould. Loam moulds yield a greater amount of such impurities than dry or green sand. They rise to the top and the shrink-head is cut off from the finished casting, leaving sound and solid metal beneath. This form of cylinder with internal flanges is a common and simple job. The mould is formed of two parts; the core and the cope; each is swept on the same principle as the loam cores. It is first necessary to obtain a strong circular plate upon which the whole structure is to be built. This plate for a cylinder 40 inches in diameter and 60 inches long should be at least 2 inches thick. It should not be less than 60 inches in diameter and be provided with 4 projecting lugs to which the hoisting tackle may be attached. It is first placed upon a solid blocking and leveled. Through the hole in the center a spindle is run, similar to that shown in Fig. 67. This spindle should be held at the top as well as the bottom, and rise at least 2 feet above what is to be the top of the mould. It will then clear the cap and hoisting bar.

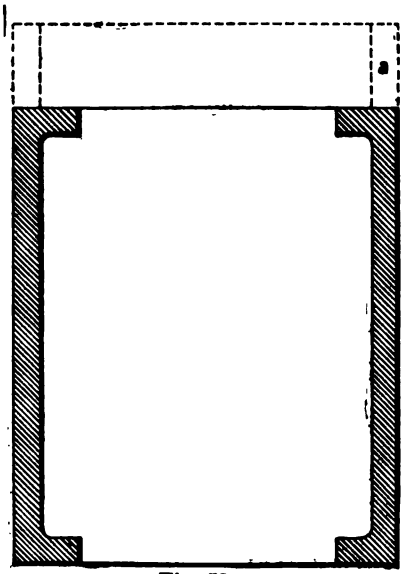


Fig. 72.

Fig. 73 shows a section of a loam mould constructed for the casting of a cylinder like that of Fig. 72. The spindle *a* is shown with its step *b*. The base ring *c* supports the whole mould. The first thing to be done is to cast the base ring *c*, the cope ring *d*, the core ring *e* and the cap ring *f*. All of these rings may be made in open sand moulds. As already noted, the base ring *c* must be large enough and heavy enough to carry the whole weight of the mould, when slings are attached to its lugs *g g*. The cope ring *d* must be of the same outside diameter as the base ring. Its inside diameter, however, should be about 2 inches larger than that of the finished cylinder. It must be strong enough to carry the cope. Lugs are also cast on the outer edge

by which the cope may be lifted. The core ring *e* is simpler and may be lighter. It has to carry the overhang of the core. The cap-plate or ring *f* is cast with bars projecting downward from the under side. These serve the same purpose as the bars of an ordinary cope.

Loam moulds of the character about to be described are built up of common red brick. They are set in a mortar composed of

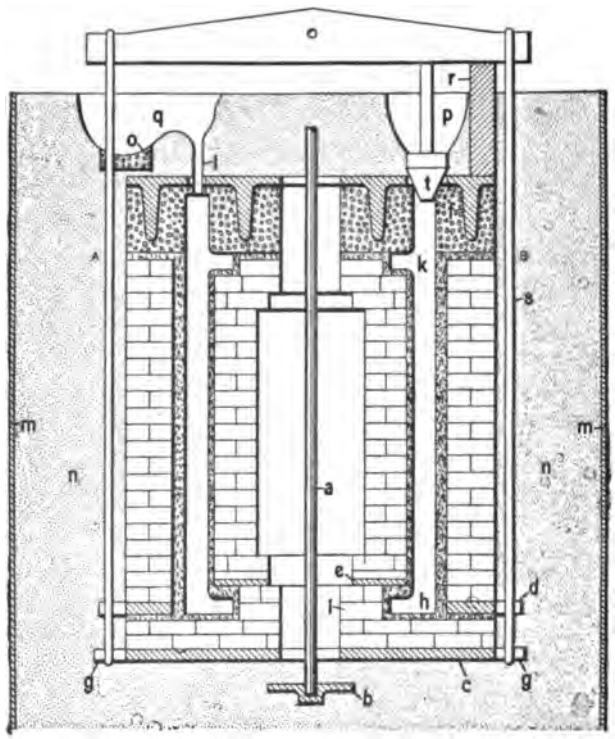


Fig. 73.

mud made from the scrapings of the foundry floor, and are smeared on the mould side with loam.

The first thing to be done in the case under consideration is to set the base plate firmly on the floor or blocks and central with the spindle. On this lay a ring formed of two courses of bricks. Set them as closely together as possible and have the spaces between them well filled with the mortar. The first sweep to be

fastened to the spindle may be a plain board like that of Fig. 67. The outer edge *c* Fig. 67, swings on a radius equal to that of the cylinder to be made. Over the first layer of brick spread a layer of loam about $\frac{1}{2}$ inch thick at the outer side. Sleek this off and finish. Before proceeding it must be dried. This may be done by hanging a charcoal fire in a basket over it. On this lay the core plate *d* Fig. 73. The bricks should be carefully laid and stand off about an inch from the outer end of the sweep. After the bricks are laid the loam is to be rubbed on and swept off to the proper radius with the board. This first coating of loam will have to be partially dried by hanging a charcoal fire in front of it. The finishing coat or *skinning loam* is then applied. Skinning loam is the ordinary loam thinned with water. After the cope has been built up to the parting line A B and partially dried it is ready for the blacking. Flat brushes should always be used for this work, as they spread it more evenly than either a round brush or a swab. The blacking should be laid on to a thickness of about $\frac{1}{16}$ inch. Spread the blacking carefully and do not sleek. Where sleeking is done on the convex surface of a cope the skin of the loam is easily loosened and will be likely to scab.

After the cope has been finished marks are made on it and on the base, so that it can be replaced in the same position in which it was built. It may then be lifted off and sent to the oven for drying.

The next operation is the building up of the core. The first sweep used resembles that of Fig. 67; the second has an undercut on the outer end to form the flange *h* as shown in Fig. 74. Carry out the coating of loam on top of the base bricks and sweep smooth with the board of Fig. 67. Cover it with a layer of skinning loam. Let it harden and then throw on a sprinkling of parting sand. Change the sweep and use the one shown in Fig. 74. The flange beneath the core must be formed with sand. Use old sand and some that is well sifted and *tempered*. Tempering is the term applied to the cutting up and dampening of the sand, when it is being prepared for the use of the moulder. Pack the sand in by hand and sweep it off. Dampen it and sleek it down until it clears the sweep. Then finish it off with skinning loam. This surface must now be prepared to give an impression to the

core. This can be done by swabbing off the surface with coal oil and sprinkling on some parting sand before it has dried.

The sweep used for the flange is now removed and an overhung one as shown in Fig. 75, put in its place. While working near the bottom of the core the overhanging piece *a* had best be stayed by a supplementary connection to the spindle like the bar *b* at the top. This is to be removed when the brick work has risen to that height. First lay up the brick work at *i* Fig. 73, until it has risen about 1 inch above the top of the sand flange *h*. Lay on the loam as the work progresses. Put the core plate *e* in position. This plate should have pin projections on the lower side to steady it. Proceed with the laying of the brick of the core in exactly the same manner as that pursued with the cope. Let the brickwork stand about an inch inside the sweep *a* of Fig. 75. Cover it with loam and finish in the same way as in the case of the cope. A fourth sweep must be added to sweep the upper flange *k* Fig. 73. The cope and core both end at the parting line A B. When finished and before drying, the sand forming the false flange *h* must be removed. Above this the mould may be of dry sand carried on the cap *f*. In this cap a series of holes *l* are cored through which the metal is poured. When the core is finished it is lifted by the base-plate *c* and carried to the oven.

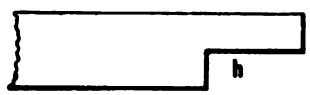


Fig. 74.

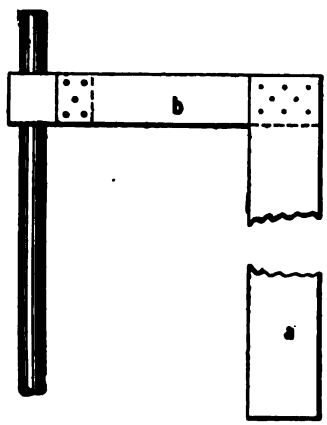


Fig. 75.

Sometimes, in the case of cores too large to be placed in the oven, the drying is done by means of charcoal fires.

After the loam work has been dried, a pit is dug in the floor for casting. It should be deep so that the ladle can be conveniently worked above the mould. Ram a level bed in the bottom of the pit to receive the base plate and lower the whole mould into position. As the outward pressure of the iron upon the cope is very great, it must be sustained in some way for the brickwork

alone would have insufficient strength. The best way is to surround the mould by a boiler plate curb *m m*, and ram the intervening space *n n* with sand. If a curb cannot be obtained the pit may be dug out to the solid earth and rammed. The curb is the better method.

After lowering the mould into the pit the covering above the cover plate is made of sand. In this there is a riser *p* and a pouring basin *q*. It is well to protect the bottom of the latter with a core *o*, so as to prevent sand from being washed into the mould. When everything is in position it is well to clamp all parts together by placing a wedge *r* between the supporting bar and the cover plate. This puts a tension on the suspension rods *s* and holds all the parting surfaces in close contact.

The hole between the shrink head and the riser should be plugged with a weight *t*. This plug is to be kept in position until the iron touches it, when it should be instantly raised. The object of keeping the plug in and the riser closed is to put an air pressure on the mould. Such a pressure serves to bind all of the parts together. This course is, however, not always followed. Some moulders prefer to leave all risers open. It is well, when pouring to have a small fire of shavings in the core. The object is to rarify the air and heat the parts.

The principal precautions to be taken in loam moulding of this sort are: to have the loam well dried before pouring; to provide suitable shrink-heads and risers for the reception of the impurities that may arise; to have the brickwork well supported by sand rammed about the outside; to ram the sand harder near the bottom than at the top for it has to sustain the greater pressure at the former point; and to be sure that all dimensions of the mould are accurate.

In case of very large castings the moulds are frequently built in the pit and dried in position by charcoal fires.

Engine Cylinder. One of the most common jobs of moulding that is done in loam is that of large engine cylinders. In this work partial patterns are usually provided. These patterns ordinarily consist of the core boxes for the ports and adjacent parts. The core and the cope are built in a manner similar to that

described for the simple cylinder with internal flanges. Fig. 76 illustrates a vertical section of the mould of a steam cylinder. In this case the flanges are upon the outside of the cylinder. Here they serve to hold the studs for bolting on the cylinder heads. In the building up of the cope, a plate *a* is built into the brickwork to carry what now becomes an overhang of the cope instead of an

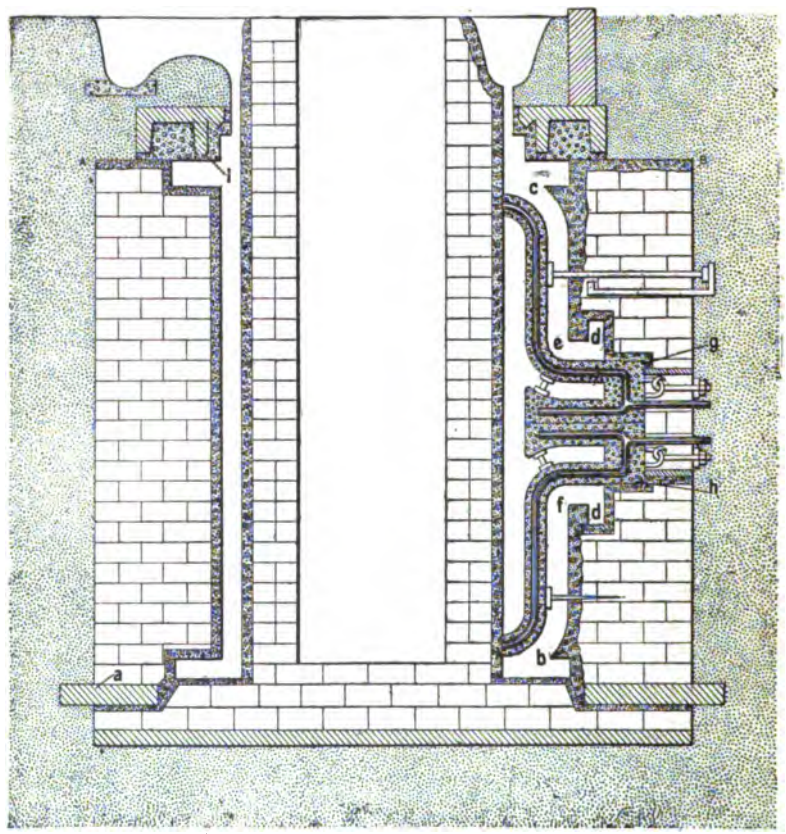


Fig. 76.

overhang of the core as in the previous example. This plate is of the form shown in Fig. 77. A part is cut away at *a* Fig. 77, to permit of the placing of the pattern which is to form the print for the core which forms the steam passages and ports. This plate should be seated on the lower layer of bricks as already described for the simple cylinder. In general the use of a pattern in con-

nection with loam moulding is troublesome. The pattern must be well oiled in order to prevent the loam from sticking to it. After the pattern is withdrawn the mould must be well washed. If all of the oil is not washed from the loam the finishing coat will not stick to it and the mould will be apt to scab. For these reasons some moulders prefer to build the loam for the core prints from drawings. Where a pattern is used, as in Fig. 76, it should reach from the point *b* to the point *c*. The overhung flanges of the steam chest at *d d* are made in loose pieces that are left in the mould when the main pattern is withdrawn and are themselves removed afterward. The pattern should be made so as to present a surface for the outer surface of the steam passages from *c* to *e* and from *b* to *f*. It also carries a core print extending back into the brickwork to the points *g* and *h*. This pattern should be accurately set when work is commenced on the cope. Measure up from the lower end of the cylinder to the center. Fix the center of the pattern at that point. Hold the pattern in position by props and stays so arranged as not to interfere with the progress of the brickwork. Oil the face of the pattern, which is to come in contact with the loam, with coal oil and build the brick work around it. Let the bricks be about an inch from the pattern and fill the intervening space with a stiff loam. At the center, opposite the location of the ports, pipes should be built into the brickwork. These pipes serve the twofold purpose of permitting the admission of bolts to hold the cores in position and of providing a means of escape for the generated gases. After the brickwork has been carried up to the parting line A B the pattern is withdrawn. Carefully wash away all of the oil that may adhere to the surface of the loam. Then apply a coat of skinning loam as directed for the simple cylinder. After this the mould is to be blackened and dried as before. The cap-plate *i* does not differ essentially from the one that has already been described. Above the cap-plate are placed the pouring basins and runners as before. The mould is

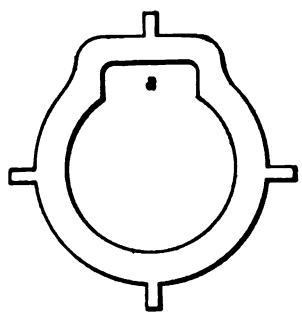


Fig. 77.

strengthened by ramming sand about the outside as in the case of the simple cylinder.

Loam moulding is extensively used for large castings where only a few, possibly but one of a kind are to be made, and where complete patterns would be expensive. It is also a convenient method of making large complicated castings where, if they were to be moulded in green or dry sand, three, four or five-part flasks would be required. Other instances of a common use of loam moulding are to be found in screw propellers, kettles, condensers and the like.

Loose Pieces. In the description of the moulding of the last example, a reference was made to loose pieces on the pattern that do not draw out of the sand with the main body. Loose pieces are used where it is desired to avoid the placing of a core or where core prints are to be made. Thus in Fig. 78, if the pattern were imbedded in the sand of the drag with a parting line at A B, it could not be withdrawn unless the pieces *a a* remained in the sand. These pieces are therefore made loose and then drawn out on the angle at which they are set after the main pattern has been removed from the sand.

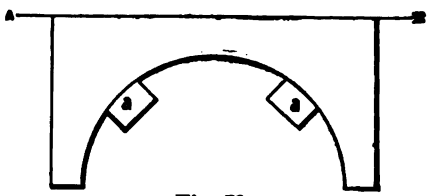


Fig. 78.

SECTION 3.

FORGING.

The art of forging is one of the oldest in the history of man. As already noted in "Foundry Work," while the art of smelting must have preceded that of forging, the latter antedated by many centuries that of making castings of iron. It is probable that in the early years the metal was rare and costly. Its being used for personal adornment seems to prove this. Such examples are the iron finger rings found in the tombs of the ancient Egyptians. Comparatively few specimens of ancient wrought iron work have been discovered however. This is due to the fact that it rusts so readily. Gold, silver and bronze, on the other hand, do not corrode rapidly. According to Pliny the best steel used by the Romans was imported from China, where iron is said to have been worked as early as 2000 B. C. During the Middle Ages iron working reached a high state of development in Europe. This is shown in the beautiful designs of wrought iron found in the churches and palaces of the time. Hinges, brackets, balconies, knockers, grills, armor and weapons were executed of the most intricate and artistic designs. The entrance door of the Hall of Merton College, Oxford (shown in Fig. 1), is an example of this work.

Although this work was beautiful and delicate, it was all light and could be made by hand. The forging of the heavy frames and shafts that we have to-day would have been impossible with the appliances then available. The steam engine makes present forgings possible.

The work of the smith became changed somewhat when the art of making castings was discovered. From this time on, the delicate, intricate designs were made by casting and the smith devoted himself to making forgings of strength rather than beauty. As the demand for artistic forgings decreased, that for mechanisms increased until to-day artistically hammered work is counted among

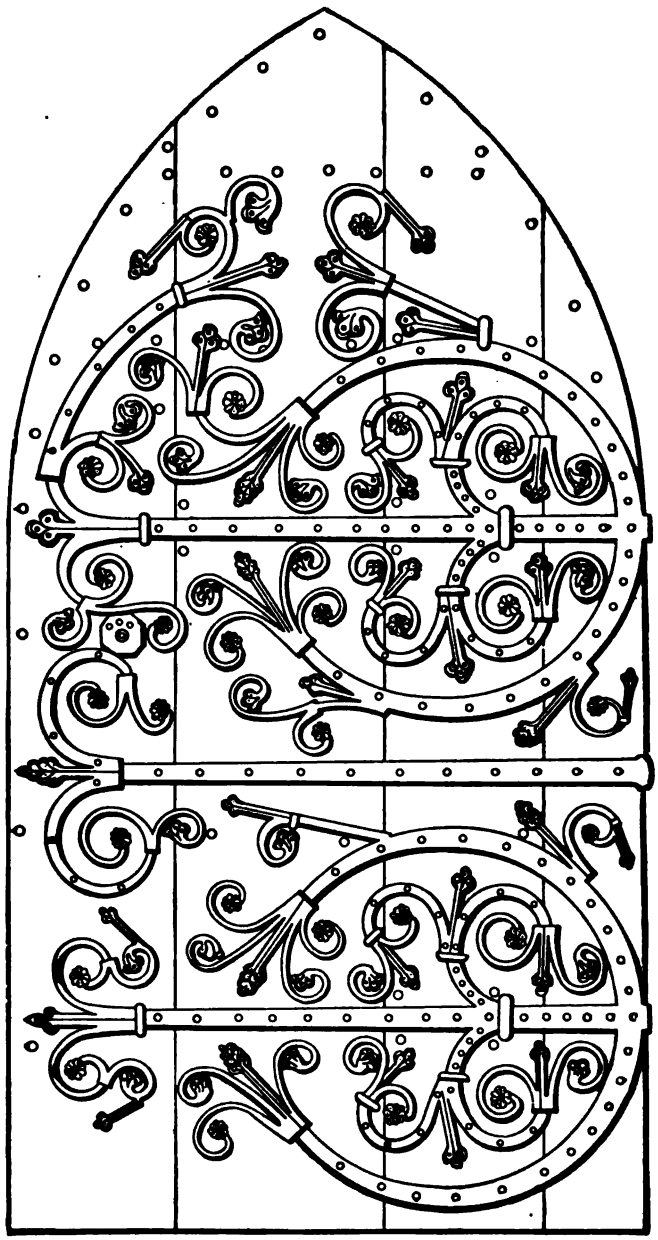


Fig. 1.

the luxuries of the few. The products of the forge find application in all grades of modern mechanisms, from a lady's watch to armor of a modern battleship.

The Materials upon which the work of forging or blacksmithing is done, are wrought iron and steel. As explained in "Metallurgy," wrought iron is an iron from which "the silicon, phosphorus and most of the carbon has been removed." Steel usually contains some of the impurities that are characteristic of cast iron with the marked peculiarity of holding a varying percentage of carbon. Mild steels are so-called on account of the small amount of carbon which they contain. As the percentage of carbon increases, it becomes more difficult to weld the metal. Greater care must also be used in heating lest the metal be burned and its strength destroyed. Until recently all heavy forgings involving welding, were made of wrought iron, but new processes have made it possible to weld steel. It is now possible to procure heavy steel castings that may be bent, twisted and when broken, can be welded.

The properties which it is necessary for a metal to possess for forging are ductility and malleability. Many of the steels are not welded but are hammered into shape from a single original piece. The various kinds of steel are described in "Metallurgy."

The Shop may vary in size from the small blacksmith shop with a single forge to the great establishment fitted with ponderous steam and power hammers and innumerable fires and furnaces. There are, however, a few common characteristics of all such shops. The floor should be of earth or cinders. The ground beneath should be well drained. A good method of laying a floor is to excavate to the depth of about 18 inches and fill in 12 inches of this with broken stone. Cover with a layer of finer stone and use earth for the top. This makes a macadamized floor. If the shop is connected with a machine shop, the floor can be still further improved by covering to a depth of $\frac{1}{2}$ inch or so with cast iron chips. When these have been wet a number of times they rust together and form a hard even surface.

The walls of the building are preferably of brick. The roof may be of wood or iron, with a slate covering. It should also contain a monitor ventilator along the ridge pole through which

smoke and gases may escape. If iron work is used in the construction of the roof, it should be thoroughly protected from corrosion by an asphalt or graphite paint. The side walls should be amply supplied with windows, and the ventilation should be as complete as possible.

A distinction is usually made between a blacksmith shop and a forge shop. The difference lies in the weight of the work and the method of doing it. In the blacksmith shop, the work is usually done by hand and is heated in open fires. In the forge shop machinery is employed to do the work, which is heavier, and the heating is done in a closed furnace. The difference is, therefore, one of degree and not of kind. The two classes of shops will be treated separately.

The Forge. While forges or fires are of many shapes and sizes the principles of their construction remain the same. An ordinary blacksmith forge is a fireplace in the bottom of which there is a tuyere for admitting a blast of air to blow the fire. Where the air blast is furnished by a hand bellows the pipe leading therefrom to the tuyere is open throughout. Where a power-driven blower furnishes the blast, there is a valve in the pipe for regulating the same.

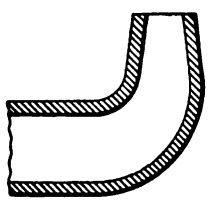


Fig. 2.

Fig. 3.

The usual form of tuyere consists of a single blast pipe, opening into the bottom of the fire pit. This may be a simple nozzle as in Fig. 2, with the blast regulated by a damper in the pipe; or, it may have a regulator at the mouth of the tuyere as in Fig. 3. Sometimes the tuyere has several openings, and is then in the form of a grate. Whatever its form, it should be possible to clean it from below, in order that coal and clinkers falling into it may be removed.

A common form of forge is shown in Fig. 4. It is built of brick and the chimney rises from one side. A bonnet (*b*) placed above the chimney opening increases its draft. The fire is at one

side and only comparatively light work can be done in it. An improved form of forge is shown in Fig. 5. In this the fire is at the center. The smoke and gases are carried off through a bonnet suspended from above. With this construction it is possible to work on all sides of the fire and long bars may be heated at any point.

The Fuel used in the forges thus far described is invariably bituminous coal. It is desirable that the coal should be as free as possible from sulphur and earthy matter. Sulphur gives off choking fumes that are disagreeable and it has an injurious effect upon the iron. Earthy matter produces clinker and chokes the tuyeres. A coal that contains a great deal of gas is also undesirable. Gas distilled from coal cannot be burned in an open fire. Formerly, almost all blacksmith coal was imported. Now, however, such coal as that mined in the Cumberland region is admirably adapted to the purpose. Cumberland coal averages about the following composition:

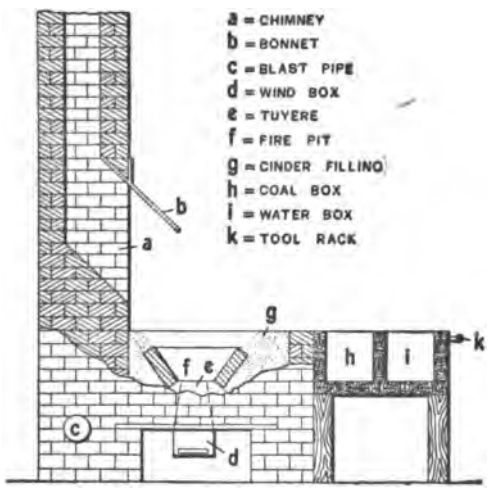


Fig. 4.

Carbon	93.81 per cent.
Hydrogen	1.82 per cent.
Oxygen	2.77 per cent.
Ash	1.60 per cent.
	100.00 per cent.

From this it will be seen that carbon stands very high and that the losses due to the distillation of hydro-carbon gases must be very low. Anthracite coal is used in special furnaces, which will be described later. Charcoal and coke are also used in limited quantities.

The Blast is furnished to the fires of a blacksmith shop by blowers of various kinds. For many years the ordinary bellows was used. This has been superseded by the fan blower which is now almost universally used, even for hand power.

Such a fan blower is shown in Fig. 6. It is formed of a thin cast iron shell in which there are a set of rapidly revolving blades.

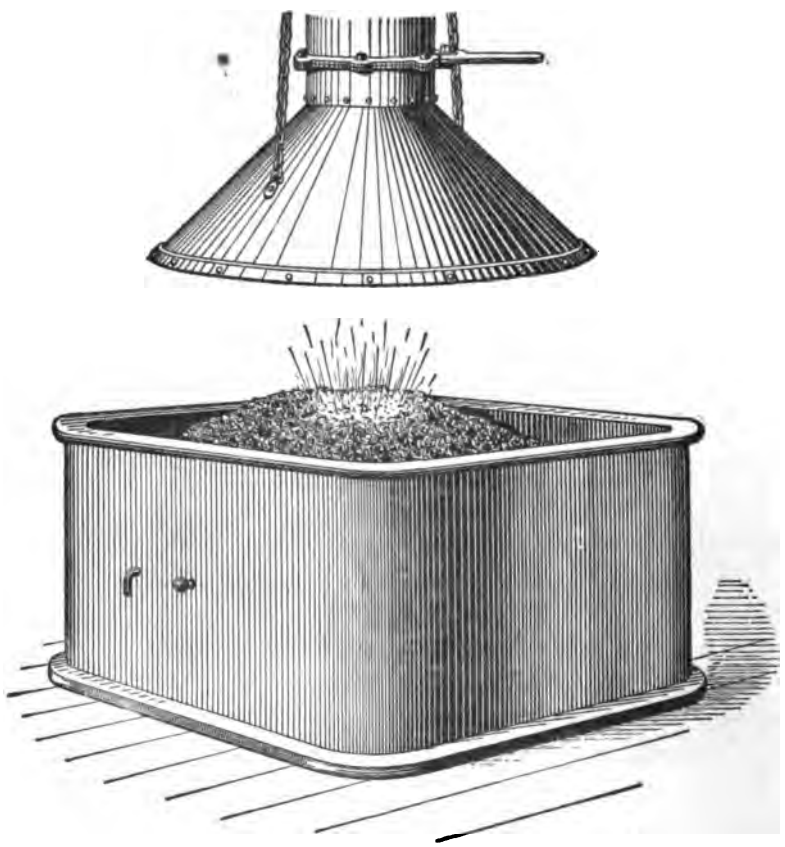


Fig. 5.

These blades set up a current of air which presses against the side of the shell and escapes through the tangential opening. The pressure of the blast used for an open blacksmith fire varies from about 2 to 7 ounces per square inch. The lower pressure is used for a light fire and light work. The higher pressure is suitable for heavy classes of work.

Tools. The tools used in a blacksmith shop are of the simplest description. The most important are the hammer and anvil. Then come the tongs, flatters, swages, drifts, fullers, punches, calipers, etc.

Hammers differ in weight more than in form. The common shape of hammer used is the ball pene hammer shown in Fig. 7.

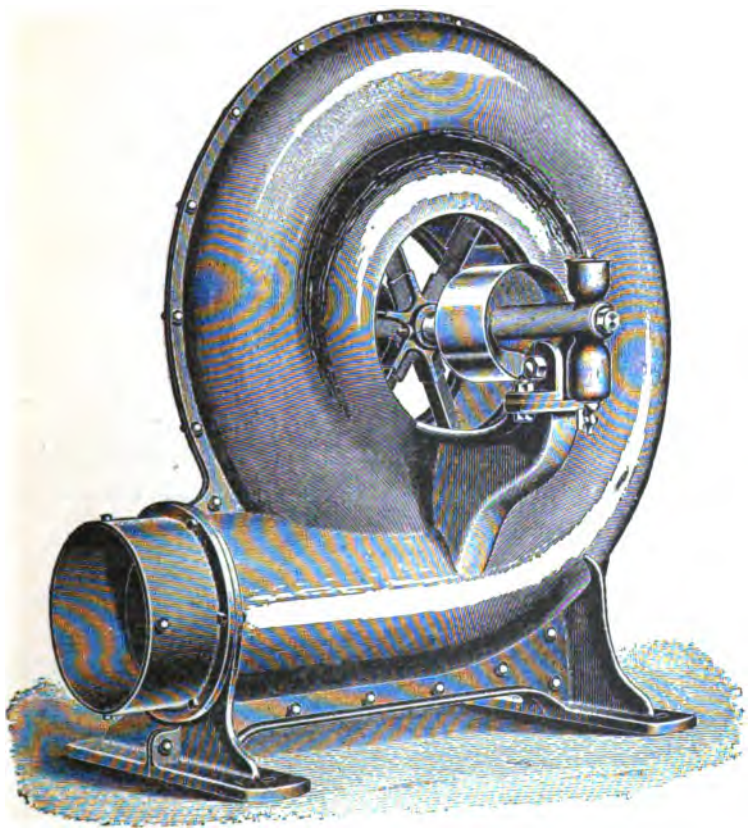


Fig. 6.

In weight they vary from five or six ounces to three or four pounds, and are used according to the work in hand. The effect of a blow from a hammer depends upon the weight and the speed. A heavy hammer produces a deeper effect upon the metal than a light one. The reason is that the force of a light blow is easily absorbed by the metal in the immediate vicinity of the surface.

A heavy blow cannot be absorbed as readily, hence the metal shows the effect for a greater distance from the surface. This is illustrated by the rivets shown in Figs. 8 and 9. In Fig. 8 the metal at the end of the rivet is turned over by blows from a light ham-

Fig. 7.

mer. In Fig. 9 where a blow was struck by a heavy hammer, the metal is upset for nearly the whole length of the rivet. There is no sudden enlargement at the end, but an increase in size for some distance there-from.

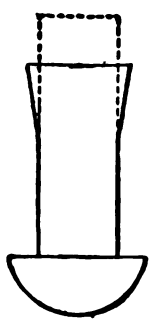


Fig. 8.

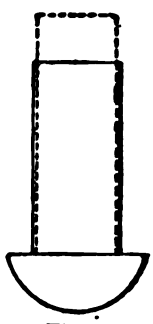


Fig. 9.

Fig. 10.

Another form of hammer is shown in Fig. 10. This is the sledge hammer, and is used for striking heavier blows than can be given with the ball pene hammer of Fig. 7. The peen of this hammer is straight and rounded on the edge. Such hammers weigh from five to twenty pounds.

In the fitting of the handle to the head great care should be taken. Hammer handles are made elliptical in cross section. The major axis of this ellipse should exactly coincide with that of the eye of the head. The reason is that the hand naturally grasps the handle so that its major axis lies in the direction of the line of motion. Hence, unless the handle is properly fitted in this particular, there will be constant danger of striking a glancing blow. The handle should also stand at right angles to a center line drawn from the ball of the pene to the face. The eye in the head is usually so set that the weight on the face side is greater than that on the pene. The effect of this is to so balance the tool that heavier and more accurate blows can be struck than if the weight were evenly balanced on each side of the eye.

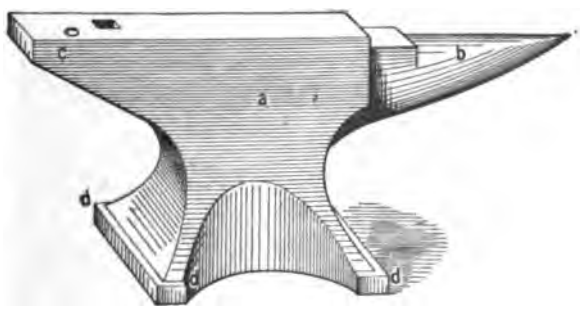


Fig. 11.

Anvils. Next to the hammer in importance is the anvil. This may be any block of metal upon which the piece to be shaped is laid. The anvil must be of such a weight that it can absorb the blows that are struck upon it without experiencing any perceptible motion in itself.

It can be shown that if a body impinges upon another of equal weight, the two will thereafter tend to move at a velocity equal to one-half of that originally possessed by the impinging body. Suppose a sledge hammer weighing fifteen pounds to be moving at the rate of 10 ft. per second. If it were to strike upon an anvil of the same weight the two (the hammer and anvil) would tend to move down at the rate of 5 ft. per second. But if, instead of this, it were to strike upon an anvil weighing 400 lbs. the tendency of the two (the hammer and anvil) would be to move on at a speed

of but .36 foot = 4.3 in. per second. This velocity is easily checked and absorbed by the elasticity of the blocking on which the anvil rests.

The ordinary anvil, Fig. 11, has remained unchanged in form for many hundreds of years. As now made, the body *a* is of wrought iron to which a face of hardened steel is welded. From one end there projects the horn *b*, and the overhang of the body at the other end *c*, is called the tail. At the bottom there are four projections *d*, called the feet, which serve to increase the base upon which the anvil rests as well as to afford the means for clamping it down into position. In the tail there is a square and a circular hole. The former serves as a mortise in which cutters and similar tools may be held.

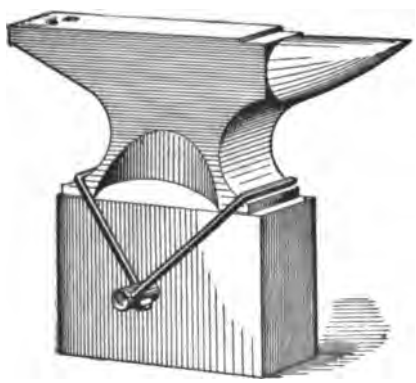


Fig. 12.

An anvil of this form serves for the execution of any work that may be desired.

Anvils are also made with a body of strong gun metal or cast iron, to which a face and horn of steel is welded.

The anvil should be placed upon the end of a heavy block of wood sunken into the ground to a depth of at least two feet, so that it may rest upon a firm but elastic foundation. As the anvil is subjected to constant vibrations, by the nature of the work, it is necessary that it should be firmly fastened to the block. In doing this avoid spiking, as the spikes will soon work loose and the block be spoiled. A very convenient and reliable method of holding the anvil is shown in Fig. 12. Here, there are two iron rods about $\frac{3}{8}$ in. in diameter passing over the feet of the anvil and running through a 1 inch round or square bar extending through the block. Nuts on these rods make it possible to draw them very tight and thus hold the anvil firmly.

Tongs. Next to the hammer and anvil in importance and usage are the tongs. They vary in size from those suitable for holding the smallest wires to those capable of handling ingots and bars

of many tons in weight. The jaws are also adapted to fit over the piece to be handled and are of a great variety of shapes. As the requirements of each piece of work varies so much from that which precedes and follows it, it is customary for the blacksmith to dress his own tongs and adapt them, from time to time, to the work he has in hand. Comparatively few, therefore, of the various shapes of tongs found in shops are manufactured and for sale. A few of the general types and forms in common use are here given.

Fig. 13 represents the simplest form of tongs. These are known as flat tongs from the shape of the jaws. They are used for holding flat pieces of metal, and vary in size according to the work in hand.

Fig. 13.

Fig. 14 shows a pair of pick-up tongs. These are used for picking up hot pieces of metal that may have fallen upon the floor. They are usually light and have long handles so that objects on the ground may be reached without stooping.

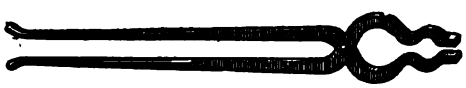


Fig. 14.

Fig. 15.

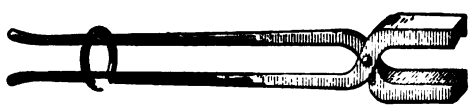


Fig. 16.

Round bit tongs are illustrated in Fig. 15. The jaws are concave and are suited for holding cylindrical objects. Tongs of this kind are frequently made of great strength and weight and are adapted to the handling of heavy shafts and axles.

Similar tongs are used for holding square pieces. In such, the jaws have a rectangular recess as in Fig. 16, instead of a circular one. A square piece can thus be held more securely by gripping on the corners than where it is seized on the flat surface.

A common modification of these last two forms of tongs is shown in Fig. 17. These are called hollow-bit tongs. The jaws open out between the end and the pin, so that they are fitted for seizing objects that are enlarged at the extremity. It is a con-

venient form for handling bolts upon which the head has been upset, also similar pieces. The tongs with jaws as shown in Fig. 16 are also made in the same way.

Pincer tongs, Fig. 18, are useful for many purposes, as in holding a piece that has a rounded projection rising from the main body. A modification of this form is shown in Fig. 19.

These are the principal shapes that are to be found in all shops. As already stated, there are innumerable modifications of them. A convenient form is the box tongs, Fig. 20, where one jaw is lipped down on its edges to steady the sides of a flat piece of work. Another form is shown in Fig. 21.

Fig. 17.

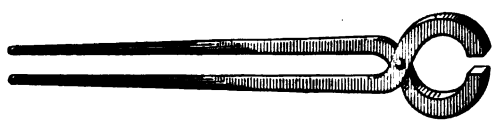


Fig. 18.

Fig. 19.

Fig. 20.

Fig. 21.

Tongs are used for holding metal that is at too high a temperature to be held in the bare hands ; for placing iron in and removing it from the fire, and work of a similar character. As the hand should be free to manipulate and turn the metal, the tongs are held in position by a link driven on over the handles as shown in Fig. 16. The elasticity of the latter serves to hold the work securely.

Chisels are of two kinds, those used on hot and those intended for cold work. These differ in that the hot has a thinner and sharper blade than the cold chisel. Fig. 22 shows a hot chisel and Fig. 23 a cold chisel. Both are held on handles like a hammer head. The blacksmith holds the work in position on the anvil with his left hand, while the chisel is held at the point to be cut with the right. A helper

then strikes on the head of the chisel with a sledge. The work is usually facilitated by putting an anvil cone, Fig. 24, in the square cutter hole at the tail of the anvil.

A common form of hot chisel for cutting off round bars or trimming off rough edges is shown in Fig. 25. This is known as

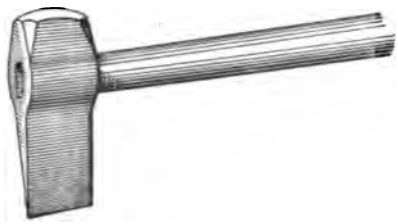


Fig. 22.

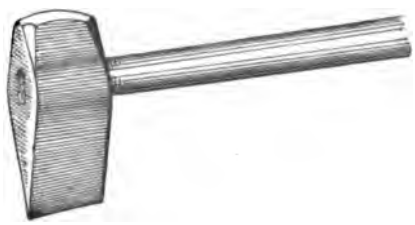


Fig. 23.

the gouge chisel. Another, but more unusual form is the square chisel shown in Fig. 26.

The Flatter is a tool in common use and is shown in Fig. 27. It is for smoothing off the surface of metal that is being

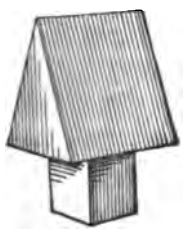


Fig. 24.

Fig. 25.

worked and thus removes hammer marks. It is held in the same way as the chisels and is struck with a sledge by the helper. Sometimes the edges are rounded. This makes it possible to work up close to rising portions and form fillets. The flatter is also made with an offset on one side as in Fig. 28. It is then called a *foot tool.*

Fullers (Fig. 29), resemble the flatters in the uses to which they are put. They are also used for working into corners, Fig. 30, where it would be impossible to strike a satisfactory blow with a hammer.

The fuller shown in Fig. 29 is known as the *top-fuller.* One set in the anvil like an anvil cone (Fig. 31), is called a ***bottom-fuller.***

Punches are also made with eyes and handles like the chisels, flatters and fullers. The extremity may be square as in Fig. 32, round as in Fig. 33, of an oblong or rectangular section, according to the work at hand. The size depends upon the hole to be punched. They are invariably used for making holes through hot

Fig. 26.

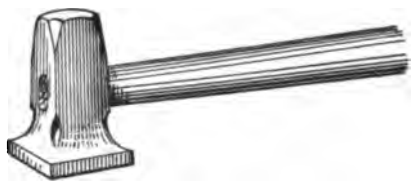


Fig. 27.

metal. The ordinary method is to punch part way through from one side; then turn the piece and drive through from the opposite direction. This avoids tearing the metal on the surface, and leaves a smooth hole at each end.

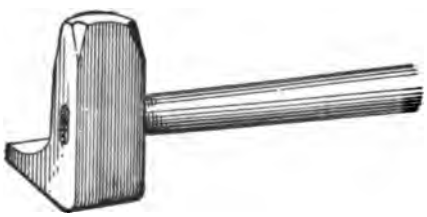


Fig. 28.

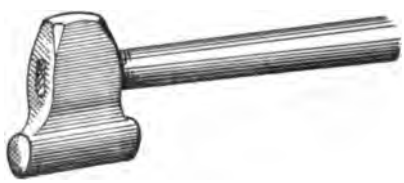


Fig. 29.

Swages are used to do work similar to that done by flatters. The difference is that they are used to form some particular shape rather than a flat surface. The most common form of swage has a concave face. It is used to smooth off a round bar. For this work a top swage (Fig. 34), which is a struck with a sledge, and a bottom swage (Fig. 35), set in the anvil are used. In connection with the use of the swage which is used for drawing metal down to a required diameter, there is another tool which is very convenient. It takes the place of both the anvil and the bottom swage and is illustrated in Fig. 36. It is usually made of cast iron of an approximately square shape, with a number of grooves of different dimensions cut on the face. These grooves are used according to the diameter and shape of the piece

being worked. It is called a swage block or a sow. The grooves at B are semi-elliptical, which should also be the shape of the curve of the top swage Fig. 34. The angular grooves are right-angled

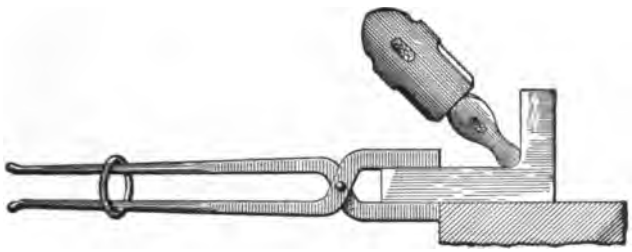


Fig. 30.

and are adapted to receive different sizes of square iron. The holes through the casting are available for punching, drifting, etc.

The tools here described embrace all the working tools that are to be used for general purposes. In addition to these, each blacksmith should have a set of outside calipers (Fig. 37), capable

Fig. 31.

Fig. 32.

of taking in the various sizes of work that he may be called upon to make. He should also have a plain carpenter's square (Fig. 38), with the longer blade two feet in length. Where a single piece of work is to have many duplications it is well for the smith to make a pair of rigid calipers (Fig. 39), with the points ground the proper distance apart. For special work many tools may be devised; some of the more common forms of which will be described hereafter.

All of these tools should be kept in a tool rack standing conveniently near the anvil and forge. This rack should be so placed as not to interfere in any way with the movements of the smith or

his helper. A common form of such a rack is shown in Fig. 40. It consists of a substantial table having two shelves. The upper shelf should be in the form of a tray. On each of the four sides there are racks *a a*, made of ½ inch round iron. By dropping the handles through the opening, the tools are held by the heads. In this position they are readily seen and the proper one easily selected for the work in hand. In ordinary blacksmith work the iron is heated before any work is done upon it. Exceptions are found in the case of cutting metal, and in heading down small rivets, both of which operations are frequently done cold. Of these the former is more often done. To sever a piece of cold metal nick a groove about the metal and bend to and

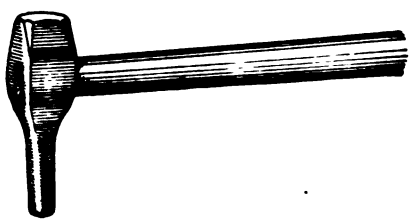


Fig. 33.

Fig. 34.

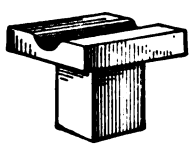
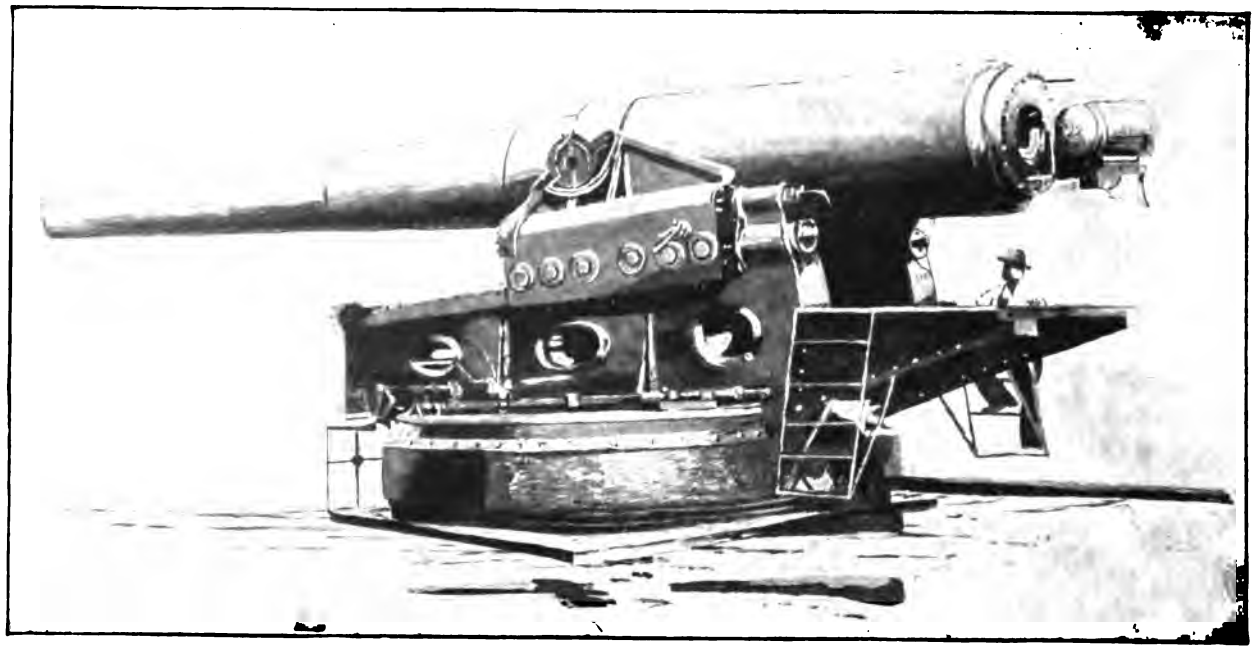


Fig. 35.

fro. All of the bending stresses are thus concentrated at the bottom of the groove, and the metal will break almost at once. The usual method of doing this work is for the smith to hold the bar to be cut in the left hand, resting it upon the anvil at the place where it is to be severed. With his right hand he places and holds the cold chisel (Fig. 23), in position while the helper strikes it with a sledge. The bar is turned between each blow so that the chisel will travel around the bar.

Heating Metals. Let us first consider the working of iron and steel. The temperature at which the different irons and steels may be heated without injury depends upon their quality. Ordinarily iron can be heated to a higher temperature than steel. The milder the steel, that is, the smaller the percentage of combined carbon, the higher the temperature to which it can be heated without injury. In other words, the less the variation of the steel



8-INCH GUN MOUNTED ON CREUSOT CARRIAGE

from the condition of wrought iron the higher the temperature at which it can be worked.

Iron and steel are heated for working in order to make them more plastic and easily shaped. The higher the temperature the

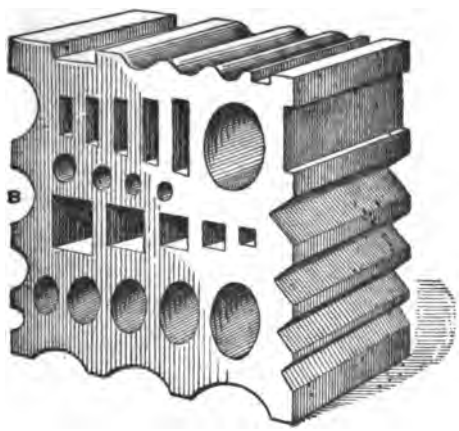


Fig. 36.

softer the metal becomes. As the metal is heated it rises in temperature and changes in external appearance. It is first black, then blue, then a dull red, then a bright red, (usually called a cherry red), then yellow; this yellow fades into a brilliant straw color which in turn fades into a white, at which point fusion takes place. The usual color at which wrought iron and steel are worked is that of a bright cherry red. Where a weld is to be made, however, the metal must be heated to a white heat. The higher grades of steel cannot be heated to this temperature without being ruined. By "higher grade" is meant steels with a greater percentage of combined carbon.

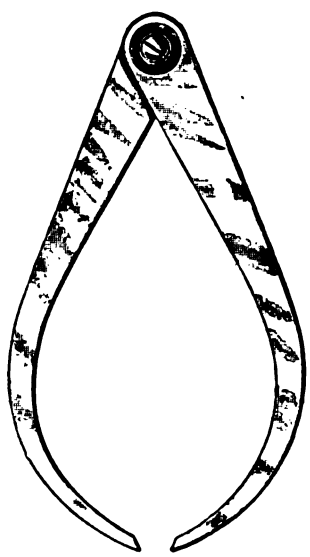


Fig. 37.

In heating metal the fire should be burned according to the work in

hand. If the three bars *a*, *b* and *c* of Fig. 41 are to be heated at the unshaded sections indicated by *d*, *e* and *f* respectively, the fire must be manipulated accordingly. In the case *a* where it is to be heated but a short distance from the end, a small fire will answer. As the forge is so constructed that a fire may be burned over considerable of its area, some means must be taken to limit the fire for small work. This is usually done by saturating the coal that covers the forge beyond the limits of the desired firepot with water. This is shown to have been done in Fig. 42. The end of the bar *a* is thrust down into the fire which is confined to the pot *g* by the wet coal *h h*. The iron should be put in that portion of the fire which is the hottest. If the end of *a* in Fig. 42 were to be put down against the tuyere, the cold air issuing from the same would prevent it from becoming hot. If, on the other hand, it were laid on the top of the fire it would radiate heat so rapidly that it would not become hot. The part to be heated must, therefore, be buried in the incandescent fuel.

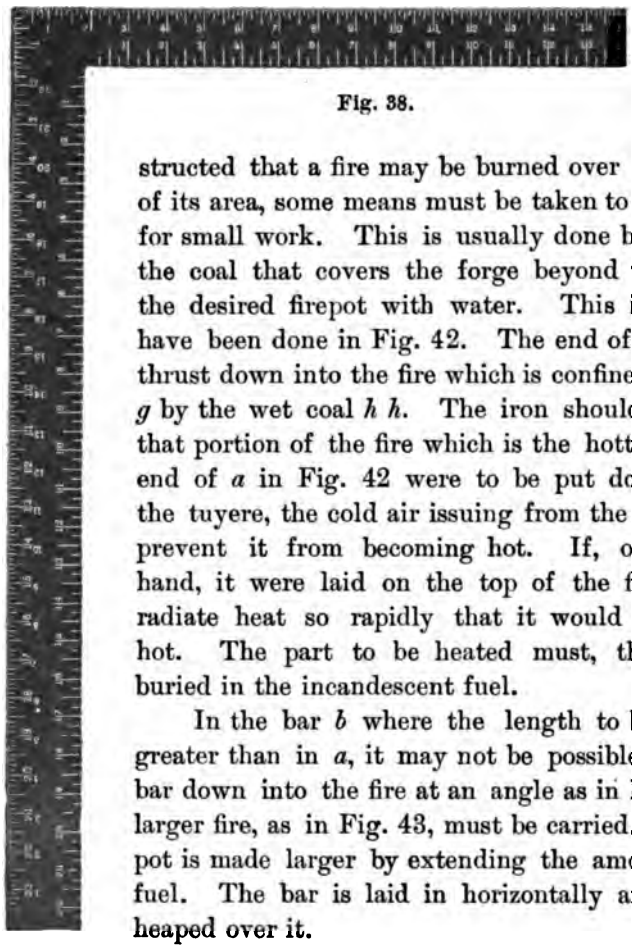


Fig. 38.

In the bar *b* where the length to be heated is greater than in *a*, it may not be possible to put the bar down into the fire at an angle as in Fig. 42. A larger fire, as in Fig. 43, must be carried. The firepot is made larger by extending the amount of dry fuel. The bar is laid in horizontally and the fuel heaped over it.

With the bar *c* the fuel is also heaped over the metal as in Fig. 44. In this case the firepot is again contracted by the use of wet coal about the edges.

These are the three typical fires. They are to be used according to the work in hand.

Wetting Coal. Combustion of coal is not greatly promoted by

the use of water. Water is used in a forge fire to limit the size of the same. By thus limiting the size of the fire the intensity of the draft through the burning parts is increased, and with it the rapidity of combustion which is in turn followed by a higher

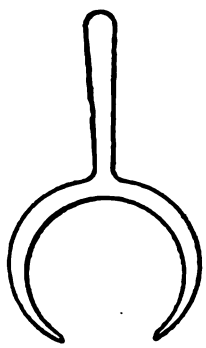


Fig. 39.

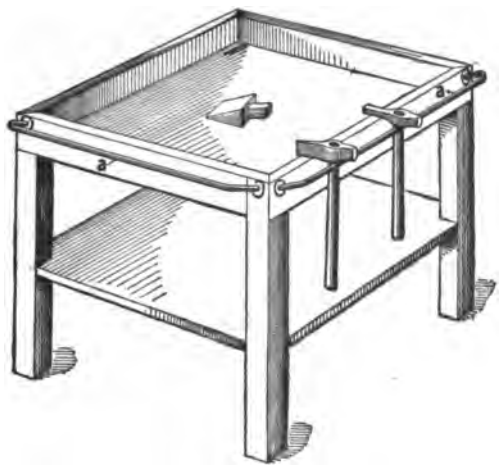


Fig. 40.

temperature. The fuel that has been wet, cakes over and cokes from the heat. This process closes the air spaces between the pieces of coal and the draft is then forced to pass up through the burning portion.

Shaping. After the metal has been heated it is shaped with the hammer. This shaping may consist of drawing, upsetting or bending. In *drawing* a bar of iron it is made longer and of a smaller diameter. *Upsetting* consists of shortening the bar with a corresponding increase of diameter. This work is usually done with a helper using a sledge hammer; the smith using a light hand hammer. They strike alternate blows. The helper must watch the point upon which the smith strikes and strike in the same place. Where two helpers are employed the smith strikes after each man. A blow on the anvil by the smith is a signal to stop striking.

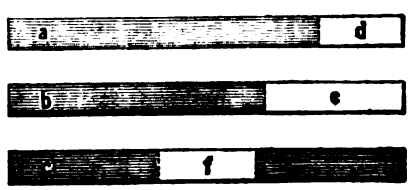


Fig. 41.

Finishing. As the hammer usually marks the metal, it is customary to leave the metal a little full and finish by the use of flatters and swages. This applies to work that has been shaped under the sledge. Light work can be dressed smoothly, and the hammer can be made to obliterate its own marks.

Wrought iron is now rolled in so great a variety of shapes

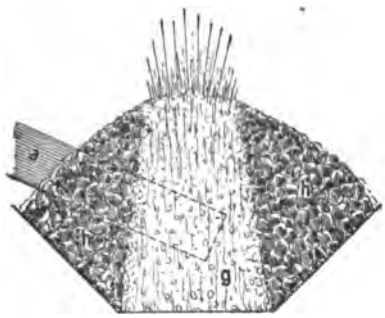


Fig. 42.

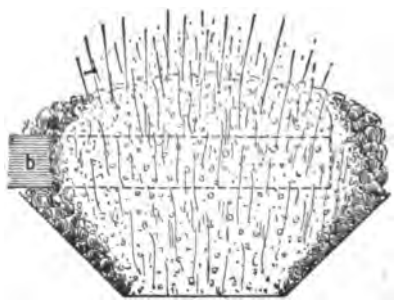


Fig. 43.

that almost any desired form can be obtained direct from the mills. The more common forms are flat, round and square. These are rolled in a great range of sizes. Besides these three there are half-round, hexagonal, etc. The table on page 23 gives the corresponding weights per foot of length for flat bars.

In the table on page 24 is given the weights for each foot of length of round and square bars.

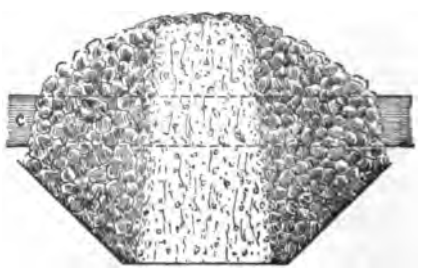


Fig. 44.

When using the table on page 23 to ascertain the weight of any size of flat iron per foot of length, look in the first column at the left for the thickness. Then follow out in a horizontal line to the column giving the width. The number given will be the weight in pounds of one foot of the desired size.

EXAMPLES FOR PRACTICE.

1. What is the weight of a bar of flat iron 1 foot long, $2\frac{1}{2}$ inches wide and $\frac{3}{4}$ inch thick? Ans. 6.25 pounds.

WEIGHT OF FLAT ROLLED IRON.

Length, 12 inches.

Thickness.	WIDTHS.																			
	⅛	¼	⅜	½	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
⅛	.208	.260	.313	.365	.417	.469	.521	.573	.625	.677	.729	.781	.833	.885	.938	.989	1.04	1.09	1.15	1.20	1.25
¼	.416	.521	.625	.729	.833	.938	1.04	1.15	1.25	1.35	1.46	1.56	1.67	1.77	1.88	1.98	2.08	2.18	2.29	2.39	2.50
⅜	.624	.781	.938	1.09	1.25	1.41	1.56	1.72	1.88	2.03	2.19	2.35	2.50	2.65	2.81	2.97	3.13	3.28	3.44	3.59	3.75
½	.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	4.17	4.37	4.58	4.79	5.00
⅝		1.30	1.56	1.82	2.08	2.35	2.60	2.86	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	5.21	5.47	5.73	5.99	6.25
¾			1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56	6.88	7.19	7.50
⅞				2.55	2.92	3.28	3.65	4.01	4.38	4.74	5.10	5.46	5.83	6.19	6.57	6.92	7.29	7.65	8.02	8.38	8.75
1					3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.91	8.33	8.75	9.17	9.58	10.00
1¼						4.22	4.69	5.15	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.90	9.38	9.84	10.31	10.78	11.25
1½							5.21	5.73	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.89	10.42	10.94	11.46	11.98	12.50
1¾								6.30	6.88	7.45	8.02	8.59	9.17	9.74	10.32	10.88	11.46	12.03	12.60	13.17	13.75
2									7.50	8.12	8.75	9.37	10.00	10.62	11.25	11.87	12.50	13.12	13.75	14.37	15.00
2¼										8.80	9.45	10.14	10.83	11.51	12.19	12.86	13.54	14.22	14.90	15.57	16.25
2½											10.21	10.94	11.67	12.40	13.13	13.85	14.58	15.31	16.04	16.77	17.50
2¾												11.72	12.50	13.28	14.06	14.84	15.63	16.41	17.19	17.97	18.75
3													13.33	14.16	15.00	15.83	16.67	17.50	18.33	19.16	20.00
3¼														15.05	15.94	16.81	17.71	18.59	19.48	20.36	21.25
3½															16.88	17.80	18.75	19.69	20.63	21.56	22.50
3¾																18.80	19.79	20.78	21.78	22.76	23.75
4																	20.83	21.87	22.93	23.96	25.00
4¼																		22.97	24.07	25.16	26.25
4½																			25.21	26.35	27.50
4¾																				27.55	28.75
5																					30.00

2. What is the weight of a bar of flat iron 4 feet 6 inches long, 2 inches wide and 1 inch thick? Ans. 30 pounds.

3. What is the weight of a bar of flat iron ½ inch thick, 3 inches wide and 14 feet long. Ans. 70 pounds.

The weight of any piece of wrought iron can be calculated in the same way as directed for cast iron in "Foundry Work," page 32, except that the constant coefficient used is .2777 instead of .2607. The rule thus becomes,

Multiply the volume of the piece of iron in cubic inches by .2777 or in the case of mild steel *multiply by .2833.*

EXAMPLES FOR PRACTICE.

1. What is the weight of a piece of wrought iron containing 1,824 cubic inches? Ans. 367.67 pounds.

2. What is the weight of a wrought iron plate ¾ inch thick and 2 feet square? Ans. 120 pounds (nearly).

3. What is the weight of a plate of wrought iron ½ inch thick, and in the shape of an equilateral triangle whose sides have a length of 24 inches? Ans. 34.64 pounds.

WEIGHTS OF ROUND AND SQUARE ROLLED IRON.

Length, 12 inches.

Thickness or Diameter in Inches.	Weight of Square Bar One-Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.
0			11/16	24.08	18.91	5/8	96.30	75.64
1/16	.013	.010	3/4	25.21	19.80	7/16	98.55	77.40
1/8	.052	.041	13/16	26.37	20.71	1/2	100.8	79.19
3/16	.117	.092	7/8	27.55	21.64	9/16	103.1	81.00
1/4	.208	.164	15/16	28.76	23.59	5/8	105.5	82.88
5/16	.326	.256	3	30.00	23.56	11/16	107.8	84.69
3/8	.469	.368	1/16	31.26	24.55	3/4	110.2	86.56
7/16	.638	.501	1/8	32.55	25.57	13/16	112.6	88.45
1/2	.833	.654	3/16	33.87	26.60	7/8	115.1	90.36
9/16	1.055	.828	1/4	35.21	27.65	15/16	117.5	92.29
5/8	1.302	1.023	5/16	36.58	28.73	6	120.0	94.25
11/16	1.576	1.237	3/8	37.97	29.82	1/16	122.5	96.23
3/4	1.875	1.473	7/16	39.39	30.94	1/8	125.1	102.3
13/16	2.201	1.728	1/2	40.83	32.07	3/16	127.6	106.4
7/8	2.552	2.004	9/16	42.30	33.23	1/4	130.2	110.6
15/16	2.930	2.301	5/8	43.80	34.40	5/16	132.8	114.9
1	3.333	2.618	11/16	45.33	35.60	3/8	135.5	119.3
1/16	3.763	2.955	3/4	46.88	36.82	7/16	138.2	123.7
1/8	4.219	3.313	13/16	48.45	38.05	7	140.8	128.3
3/16	4.701	3.692	7/8	50.05	39.31	1/16	143.6	132.9
1/4	5.208	4.091	15/16	51.68	40.59	1/8	146.3	137.6
5/16	5.742	4.510	4	53.33	41.89	3/16	149.1	142.4
3/8	6.302	4.950	1/16	55.01	43.21	1/4	151.9	147.3
7/16	6.888	5.410	1/8	56.72	44.55	5/16	154.8	152.2
1/2	7.500	5.890	3/16	58.45	45.91	3/8	157.6	157.2
9/16	8.138	6.392	1/4	60.21	47.29	7/16	160.5	162.4
5/8	8.802	6.913	5/16	61.99	48.69	8	163.5	167.6
11/16	9.492	7.455	3/8	63.80	50.11	1/16	166.5	172.9
3/4	10.21	8.018	7/16	65.64	51.55	1/8	169.5	178.2
13/16	10.95	8.601	1/2	67.50	53.01	3/16	172.5	183.6
7/8	11.72	9.204	9/16	69.39	54.50	1/4	175.6	189.2
15/16	12.51	9.828	5/8	71.30	56.00	5/16	178.7	194.9
2	13.33	10.47	11/16	73.24	57.52	3/8	181.9	200.8
1/16	14.18	11.14	3/4	75.21	59.07	7/16	185.2	206.8
1/8	15.05	11.82	13/16	77.20	60.63	9	188.5	212.9
3/16	15.95	12.53	7/8	79.22	62.22	1/16	191.8	219.2
1/4	16.88	13.25	15/16	81.26	63.82	1/8	195.2	225.6
5/16	17.83	14.00	5	83.33	65.45	3/16	198.6	232.1
3/8	18.80	14.77	1/16	85.43	67.10	1/4	202.1	238.8
7/16	19.80	15.55	1/8	87.55	68.76	5/16	205.6	245.6
1/2	20.83	16.36	3/16	89.70	70.45	3/8	209.2	252.5
9/16	21.89	17.19	1/4	91.88	72.16	7/16	212.8	259.5
5/8	23.97	18.04	5/16	94.08	73.89	10	216.5	266.7
						1/16	220.2	274.0
						1/8	224.0	281.4
						3/16	227.8	288.9
						1/4	231.7	296.6
						5/16	235.6	304.4
						3/8	239.5	312.4
						7/16	243.5	320.5
						11	247.5	328.8
						1/16	251.6	337.2
						1/8	255.7	345.8
						3/16	259.9	354.5
						1/4	264.1	363.4
						5/16	268.4	372.4
						3/8	272.7	381.6
						7/16	277.1	391.0
						12	281.5	400.5

In the actual work of the blacksmith shop one of the simplest jobs is the making of an ordinary staple, Fig. 45. The first stages of this are shown at *a* and *b* of Fig. 46. The iron is first cut to a suitable length *a*. It is then heated first at one end then at the other and pointed as at *b*. This pointing is done on the flat face of the anvil while the metal is hot. It should be noted that the pointing draws the metal out somewhat. Hence the piece is longer in the condition *b* than it was in the condition *a*. Allowance for this must be made in cutting off the metal. After pointing, the iron is bent to its final shape over the horn of the

anvil. One end is held between the jaws of a pair of flat tongs as in Fig. 47, while the other end is struck by a hammer as shown. If the iron is $\frac{3}{8}$ inch in diameter or less it may be bent cold. If more than $\frac{3}{8}$ inch in diameter it is well to heat it for more than half its length and bend while still hot after pointing. When needed in large quantities staples of this kind are made complete by machinery. U bolts, Fig. 48, are made in the same way. The threads are cut while the iron is still straight.

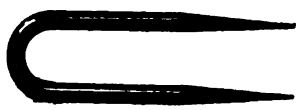


Fig. 45.

In drawing iron there is always a little waste due to the formation of scale and the action of the fuel. This is usually so small in amount that it can be neglected. Where it is possible

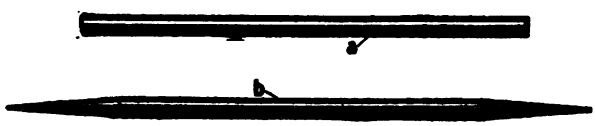


Fig. 46.

to trim the finished forging, the amount of metal originally cut off is more than sufficient to allow for the drawing or upsetting. In the case of the staple, Fig. 45, the exact allowance should be made. If it is not so made, the smith can vary the sharpness of the pointing. The more gradual the taper the longer the staple. As there is no appreciable loss of metal the weight and therefore, the bulk of the material may be considered to be the same before and after drawing or upsetting.

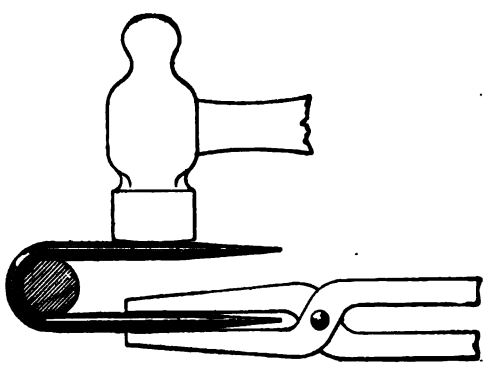


Fig. 47.

EXAMPLES FOR PRACTICE.

1. What will be the final length of a bar of round iron $1\frac{1}{2}$

inch in diameter and 6 feet long, 18 inches of which is to be drawn down to a diameter of $\frac{3}{4}$ inch.

Ans. 10 feet 6 inches.

2. A staple is to be made of $\frac{3}{8}$ inch round iron; it is to be 13 inches long over all and the taper is to extend back for $2\frac{1}{2}$ inches from the ends. What length of metal must be cut from the bar in order to make it? Ans. $9\frac{3}{8}$ inches.

Fig. 48.

3. It is desired to have a square shank having a side of 1 inch and a length of 6 inches on the end of a rod $1\frac{1}{4}$ inches in diameter. What length of the round metal will be required for the square shank?

Ans. 4.89 inches.

4. A head is to be upset on the end of a rod 1 inch in diameter. This head is to be cylindrical, $\frac{3}{4}$ inch long and $1\frac{3}{4}$ inches in diameter. What length of 1 inch rod must be allowed to make the head? Ans. 2.3 inches.

Bolts. In direct distinction from the *drawing out* of the point of the staple just described is the *upsetting* of the head of a bolt. *Drawing out* or *drawing down* may be defined as the reducing of a bar of metal to a smaller diameter or smaller cross-sectional area. *Upsetting* is the reverse of drawing out and "consists of making a thin bar of iron into a thick one," either for a whole or a portion of its length. To form the head of an ordinary bolt make the width between the parallel sides equal to $1\frac{1}{2}$ times the diameter of the bolt, plus $\frac{1}{8}$ inch. The depth of the head is equal to one-half of the width of the head. Thus, the dimensions of the head of a $\frac{3}{4}$ inch bolt are $.75 \times 1.5 + .125 = 1.25 = 1\frac{1}{4}$ inches for the length of the side and $1\frac{1}{4} \div 2 = \frac{5}{8}$ inch for the depth of the head. The cubic contents of such a head is therefore, $.625 \times 1.25 \times 1.25 = .9776$ cubic inches. As the area of a $\frac{3}{4}$ inch bar is about .44 square inch it follows that the length to be allowed for upsetting the head is,

$$\frac{.9766}{.44} = 2.22 — \text{ or about } 2\tfrac{1}{4} \text{ inches.}$$

Where large quantities of bolts are to be made the bars are heated in a furnace and headed by special machinery. Where the work is done by hand the tools are of the simplest character.

The header consists of a disc in which a hole has been drilled to correspond to the diameter of the bolt. A handle 12 or 15 inches in length is welded to the disc. Such a tool is shown in Fig. 49. The hole should be about $\frac{1}{32}$ inch larger than the nominal size of iron. To make a bolt with this tool: First cut off the iron to the required length; then heat the end to be headed, to a dull straw color; strike the end with a hammer or against the anvil and

Fig. 49.

upset it so that the portion intended for the formation of the head will not pass through the header. Then place the hole of the header over the square hole in the tail of the anvil and drop the cold end of the bolt through it. Strike the projecting portion of the bar and upset it until the requisite thickness of head is obtained. This will probably leave a head of curved but irregular outline. Remove from the header and square the head thus upset on the face of the anvil. This will probably thicken the head. Again drop the cold end through the header and strike the head until it is reduced to the proper thickness. After which, again square the edges on the face of the anvil. In doing this work, the smith will hold the header in his left hand. The work will be facilitated if a helper assists with a sledge hammer.

There are a number of simple tools in use for clamping the bar while it is being headed so as to avoid the preliminary upsetting.

We have now studied the methods to be followed in the execution of two simple jobs. One involved drawing out and the other upsetting. Sometimes both processes must be followed in one job. Where there is a choice between the two the smith should take the one involving the least amount of work.

Welding. The process of welding consists of heating the faces of the two pieces to be joined until they are at the point of fusion (called the welding heat), then uniting them by blows or pressure. The temperature of iron when at a welding heat is

1900° Fahrenheit. The appearance of the metal is nearly white and when exposed to the air it will emit bright sparks. It will also give forth a slight noise similar to that produced by the escape of a small jet of steam. The theory of welding is that the semi-liquid particles of the metal are pressed into the same condition of close contact that they have in other parts of the bar. Interposition of foreign matter between the two pieces to be joined will prevent welding. The three things that most commonly intervene to prevent welding are air, scale and dirt. Air intervenes when the two surfaces to be welded form a pocket upon being brought together. This occurs when they touch only at the edges and one or both of the surfaces are concave.

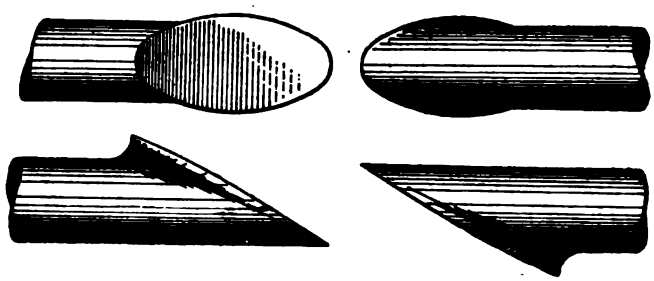


Fig. 50.

If iron is heated to any temperature above a cherry red its affinity for oxygen increases. When at a straw color or hotter the affinity is very great. This affinity results in the production of an oxide of iron known as *scale*. If scale forms on the surface of the metal between the time that it is drawn out of the fire and the weld made, it will prevent the union over such area as it covers. The welding of all metals is not done at the same temperature. Welding demands a certain condition of plasticity of surface. If this condition is not reached welding fails for want of contact due to excessive oxidation. The temperature of this certain condition of plasticity varies with the composition of the iron. For this reason irons having different welding points cannot be soundly welded to each other in an oxidizing flame.

In order to prevent the formation of scale and to permit the

welding of irons of different compositions, a flux is used. As defined in "Foundry Work," page 10, a flux is, "a substance that promotes the fusing of metals."

For welding iron, clean river sand or powdered sandstone makes a good flux. It is useless, however, for welding steel or steel and iron. For this purpose borax is generally used. The flux is applied shortly before the metal reaches the welding heat, no matter what the temperature of that heat may be. It melts on the surface of the metal, forming a slag, which covers the surface to be welded and prevents oxidation. When the two surfaces are brought together and subjected to a pressure or blows, the slag flows or is pressed out from between those surfaces and actual contact is secured.

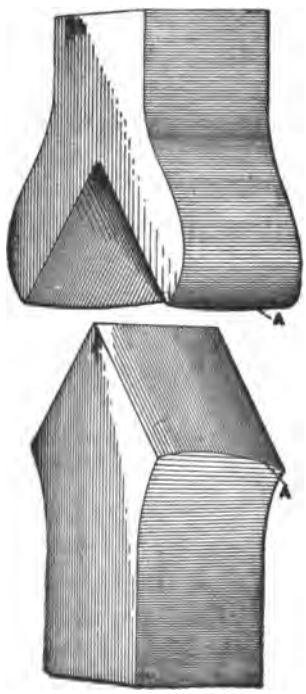


Fig. 51.

Surfaces to be welded are first shaped suitably for the purpose. Ordinarily when two bars are to be welded each is beveled as shown for round bars in Fig. 50. This beveling is called *scarfing*, and should be so done, that when the weld is complete there is but a slight enlargement of the newly formed bar at that point. For heavy work where the metal must remain in the fire for a long time in order to reach the welding heat, there is a different method of scarfing. This is shown in Fig. 51. One piece is opened in the form of a jaw, the other is wedge-shaped and fits the former. Where the weld is to be made between heavy pieces, the surfaces should be left convex as at A A in Fig. 51. This facilitates the outflow of the slag and the escape of all other impurities.

Sometimes a weld is made without scarfing; such is called a *butt* weld. This is best done by slightly rounding the ends that are to be joined, as shown in Fig. 52. As the ends are forced

together the metal flows outward forming a ring as in Fig. 53. This is then hammered down to the diameter of the bar by the use of the top and bottom swages, Figs. 34 and 35.

When a small bar is to be welded to a heavier piece of metal and a butt weld is used, it is said to be *jumped* on. Such a weld is shown at A of Fig. 54. In preparing the parts for this weld the bar should be rounded at the end as shown in Fig. 52, and the heavy piece left flat or slightly cupped. When the weld is being made the metal will flow out about the point of union. This metal should afterwards be fullered down to form a fillet as shown in Fig. 30.

The edges of the scarf will burn away to a certain extent in

Fig. 52.

Fig. 53.

heating. The scarf should therefore be made enough larger that the weld may be of full size after completion. All scarfs should be slightly rounding, in order to permit the escape of air and slag. The heating can best be done in a clear fire of coal containing little gas. In making heavy welds, heat slowly. If an attempt is made to heat large pieces too rapidly, the interior will not be heated sufficiently. Turn the metal in the fire frequently in order to heat evenly and avoid burning. Withdraw occasionally from the fire and sprinkle with flux. When welding strike light blows at first and heavy ones thereafter. As soon as the pieces are joined, strike so that the edges of the scarf will be closed. This will prevent the joint of the weld from showing when the work is completed.

Sand can be used as a flux for welding iron. For welding steel, borax should be used. To weld steel successfully the following precautions should be observed. Clean the fire of all cinders and ashes. Put sufficient coal upon the fire so that it will be unnecessary to add more coal while taking the welding heat: Upset both pieces near the end and scarf carefully: When possible, punch a hole and rivet the two pieces together: Heat the steel to a low cherry heat and sprinkle with borax: Replace in the fire and raise to the welding heat: Clean the scarfed surfaces and strike lightly at first, followed by heavier blows. The appearance of steel when at a welding heat is a pale straw color. German steel can be heated to about the same temperature as iron.

Steel may also be welded to wrought iron. This is done in the manufacturing of edged tools. The body of the tool is of iron, to which a piece of steel is welded and forms the cutting edge. This class of work is best done with a fire of anthracite coal, though coke or charcoal may be used. The fire should be burning brightly when the heating is done. Lay the iron and steel on the coal until they are red hot. Then sprinkle the surfaces of both with the flux and let it vitrify. A convenient method of doing this is to have the powdered flux (borax preferred) in a pepper-pot. As soon as the heat has changed the metals to a straw color lay them together and strike. A single blow of a drop hammer, or four or five with a light sledge will do the work. Be sure that these pieces are well covered with a flux before attempting to weld.

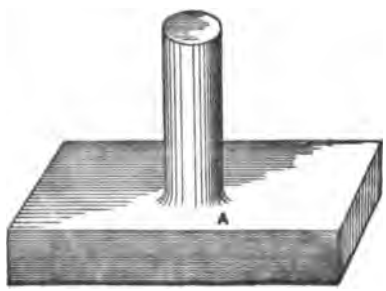


Fig. 54.

Two pieces of high grade steel can also be welded in the same manner.

No attempt should be made to do this class of work in an ordinary forge like that illustrated in Figs. 4 or 5. The forge or furnace should be especially built for burning anthracite coal. Such a furnace is shown in Fig. 55. This furnace is suited for hard coal or coke. It is fed from the hoppers shown at each end,

and can be cleaned through the pan at the bottom. The metal to be heated is laid on top of the coals beneath the brick roof.

When burning anthracite coal, the top of the bed of fuel should not be disturbed. The poker should only be used beneath. Soft or bituminous coal fires can be raked over on the top. An anthracite fire can only be retained by banking and admitting enough draft beneath the fuel to keep it ignited. The simplest method of retaining a bituminous coal fire, when not in use, is to

Fig. 55.

thrust a piece of hard wood down into the bed of coals and cover with a thin layer of ashes. To start the fire again, rake off the ashes, and put on the blast. The wood will quickly ignite and set fire to the coal.

Eye Bolt. The making of an eye bolt is a common piece of work. It may be made in either one of two ways. The easier method produces an eye shaped as in Fig. 56. To make such a bolt, first scarf the end so that it will fit over the bend of the rod

along the dotted line *a b*. Bend the eye over the horn of the anvil. Finally bring to a welding heat and weld in accordance with instructions already given.

An eye of better appearance as shown in Fig. 57 is made as follows: Upset the body of the metal as a seat for the scarf at the end, shown at *a* Fig. 58. Scarf the end of the bar and bend over the horn of the anvil into a true circle to fit the seat at *a*, and then weld as before.

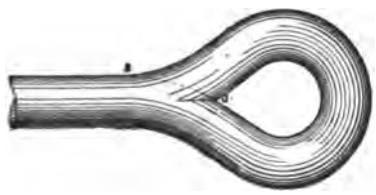


Fig. 56.

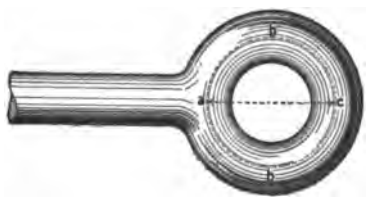


Fig. 57.

The length of metal required for an eye or ring is nearly equal to the length of the circumference of a circle whose diameter is equal to the mean diameter of the ring. Thus in Fig. 57 the length required for the eye will be approximately the length of the circle *a b c b* whose diameter is *a c*.

Hooks. The making of hooks to be used for hoisting and other purposes is important. Such a hook is shown in Fig. 59. It is made with an eye for the reception of a chain and varies in size between that eye and the point. This variation is for the purpose of so distributing the metal that the hook will be the strongest at those points where it is subjected to the greatest stress. If we consider the depth of the metal to be $2\frac{3}{4}$ inches with a width of $1\frac{7}{8}$ inches at the point of largest section, the hook shown can well be made of iron $2\frac{1}{4}$ inches in diameter.

Fig. 58.

In choosing the metal to be used for a hook, select a bar having about the same sectional area as the largest section of the hook. This will require the least amount of drawing out. For the hook shown in Fig. 59, a length of about $10\frac{1}{2}$ inches will suffice. It will be better, however, to cut off at least 12 inches

for the first one. If a number are to be made, subsequent hooks may be forged without waste. For the first it is better to use ample stock so that the work may not be spoiled. The bar should first be drawn out to the shape of the hook as in Fig. 60. As thus drawn, it will be a little longer than the inside of the hook. After drawing, weld in the eye as already directed for eyes. Then bend the hook into shape over the horn of the anvil. This bending will shorten the metal on the inner curve of the hook a very little, and lengthen it on the outer. The amount of the change in dimen-

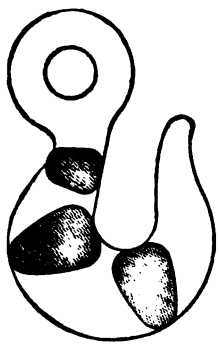


Fig. 59.

Fig. 60.

sions will depend upon the temperature at which the work is done. After completion the work should be carefully finished under the swage.

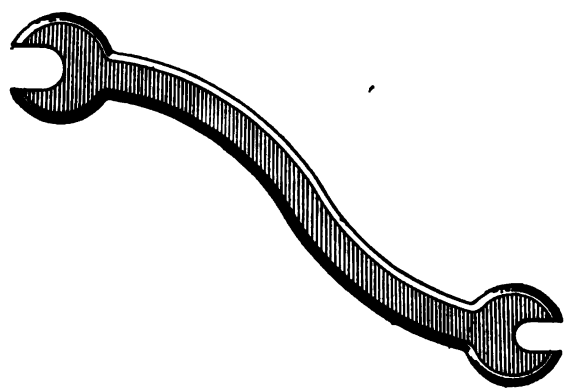
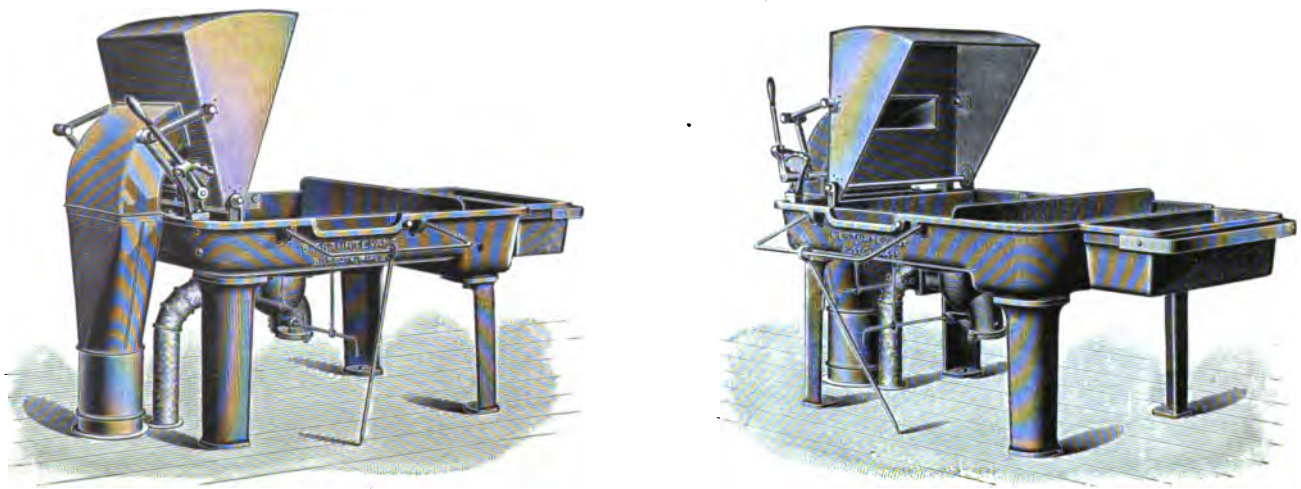


Fig. 61.

Where large numbers of such hooks are to be duplicated they are stamped out under a steam hammer or a drop.

Wrenches. A simple tool that is frequently called for is the S wrench. This wrench is usually made with a gap at each end, suited for nuts of different sizes. It is shown complete in Fig. 61.



THE STURTEVANT ADJUSTABLE DOWN-DRAFT FORGE HOOD,
As Applied to Stationary Forges.

The jaws at the end should be parallel with each other. A line drawn from one jaw to the other should make an angle of 30 degrees with the center line of each jaw. There are two ways in which such a wrench can be forged. One is to forge the jaws separately and then weld to the handle. In the other the jaws are cut from a solid piece of metal and the iron between is then drawn down to the proper size for the handle. The latter is preferable, since it avoids all welds. To make the wrench by the second process, select a piece of steel large enough to form the head. Fuller it down back of the head as shown in A Fig. 62, at *a a*. Round the end and punch the hole *b*. Next treat the other end in the same way and draw out the intermediate metal giving the form shown

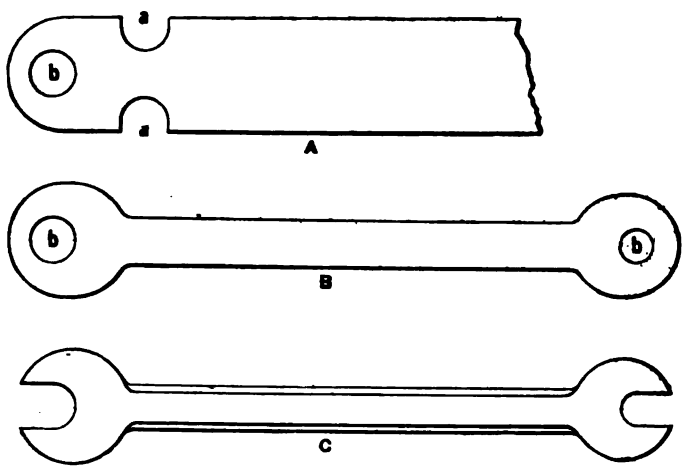


Fig. 62.

at B. Now cut out the holes *b b* securing the form shown at C. It now remains to bend the heads to the proper angle and give the desired curve to the shank. In forging such a wrench the outer edges should be slightly rounded so that they will not cut the hand. The inside of the jaws should be perfectly square with sharp edges. This finish can be best obtained by filing.

Hammer Heads are usually made in dies and by power. The various forms through which the metal passes in die forging will serve as a guide for making a hammer head by hand. If a ball pene hammer like that shown in Fig. 7 is to be made, the work can best be done from a flat bar. Take a flat bar of suitable size

for the hammer. This size is one that has about the same depth as the eye and a thickness equal to the body at that point, or enough more, so that the sectional area of the untouched bar shall be a little more than the area of the hammer's face. The heating can be done either in a soft coal fire or an anthracite furnace, as shown in Fig. 55. The latter is preferable. Heat the end of the bar only. Do not raise the temperature above a cherry

Fig. 63.

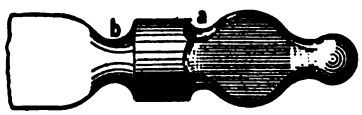


Fig. 65.

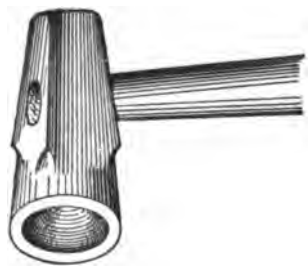


Fig. 64.

red. After the first heating hammer out the peen so that the end of the bar has the shape shown in Fig. 63. This work can be done with the fuller, Fig. 29, and the cupping tool, Fig. 64. After drawing down the end of the rod with the flatter (Fig. 27), the fuller is used to work out the groove *a*. The cupping tool, whose face is that of a hollow sphere, assists in rounding the face of the pene. The pene should first however be given a rough spherical outline with the hammer alone. If the bar is of the exact size of the body no work need be done here. If not, then forge down to approximately the proper size. Next forge the body of the hammer and cut down in front of the face, still leaving it attached to the bar as shown in Fig. 65. The grooves at *a* and *b* can be worked out with the fuller.

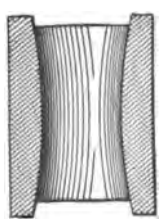


Fig. 66.

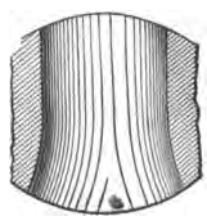


Fig. 67.

The next step is to punch the eye. This eye should not be straight. It must be tapered out each way from the center, where the eye is to be of the smallest section. The taper must run both lengthwise and across the hole as shown in Figs. 66 and 67.

To form this, the taper punch must be driven in at the two sides of the head alternately until the eye has been enlarged to the proper size.

After the completion of this work the head may be cut free from the bar. It should then be ground. If a very good job is wanted, the head should be sent to the machine shop and turned. When this has been done it should be tempered, as will be directed later.

Tongs. Every blacksmith is constantly being called upon to make his own tongs. As already stated, these tools must be of a

Fig. 68.

Fig. 69.

Fig. 70.

great variety of shapes in order to meet the demands of the shop. The different styles required are not upon the market. There are two methods of forging tongs. One is to make the jaw and handle of a single piece without a weld; the other is to forge the jaw and weld on the handle.

For light tongs the first method is preferable; for heavy, the second.

To make a pair of light tongs of the shape shown in Fig. 13, take a piece of iron $\frac{1}{2}$ inch $\times$ $1\frac{1}{4}$ inches. Forge down the ends until the bar is in the form shown by Figs. 68 and 69. Punch the eyes and split the bar into two pieces as shown in Fig. 70. Hammer the handle into a round section and rivet the two parts together.

For heavy tongs a piece of flat iron of suitable size should be forged into the jaw, after which the handles are welded. The method of doing the work in the two cases is the same, except that the forging is heavier and two welds are required.

Rings and Chains. Rings and chains are made in a manner similar to that used for eyebolts. The metal is cut off to the proper length and the ends are scarfed as shown in Fig. 50. It is then bent to the desired form of link or ring and the scarfed surfaces brought together. After reheating to the proper temperature, the weld is made. In making chains, the links are successively bent through the one preceding and then welded in position.

Tool Dressing is usually considered one of the most particular jobs in a shop. The work is light and a helper is always used for the striking. The material used is known as *tool steel.* It is a high grade of metal and contains a large amount of combined carbon. The details of this steel are given in "Metallurgy." Tools are of many shapes. Nearly all those used in a machine shop can be made with a fuller and flatter. The shank of the tool is usually left the full size of the untouched bar. This statement applies to the lathe and planer tools and cold chisels. The machine tools are made of steel having a rectangular section. Cold chisels and punches are commonly made of octagonal steel.

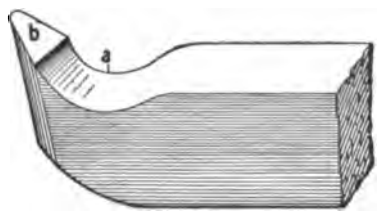


Fig. 71.

As an example of a tool to be forged take what is known as a "front tool." This tool is shown in Fig. 71. The metal used is of a size suited to enter the tool post of the lathe for which it is intended. The metal is drawn out and the hollow *a* made with the fuller. The point *b* is shaped by the hammer and cut to an approximate shape with a hot chisel. It is well to grind the tool into a working shape before tempering. It should not, however, be sharpened.

Cold chisels are made by simply flattening one end of a bar of (preferably hexagonal) steel and grinding to a suitable edge.

Double ended or sizing cutters are usually made in the machine shop and sent to the blacksmith shop for hardening. The steel of which such tools are made is first cut off and annealed in the blacksmith shop.

Tools for woodworking machinery are first cut from the bar and annealed. They are then shaped and afterwards hardened.

Tempering. The general process of tempering is described in "Metallurgy." Steel is hardened by cooling suddenly and softened by cooling slowly from a red heat. In hardening, care should be taken to plunge the tool into the water or oil vertically, so that there may be no uneven cooling of the sides. For iron working tools, plunge into the water only that portion of the tool that is to be tempered. This avoids brittleness in the supporting portions. It also enables enough heat to be stored in the metal to supply that needed for tempering.

As wood working tools are lighter, and as a partial cooling would be apt to cause warping or even cracking of the metal, it is customary to plunge them into the bath. The result is that they are cooled and hardened throughout. The reheating of these tools is done by means of an outside source, which must be capable of imparting a uniform temperature to all parts of the tool. If the heat so imparted is not uniform the tool will be warped. Where a large number of tools are to be tempered an anthracite coal fire is used. For this purpose a furnace similar to that illustrated in Fig. 55 is used. Where an anthracite fire is not available a hot iron can be advantageously employed. Take a piece of flat iron an inch or more in thickness and having a larger surface than that of the tool to be tempered. Heat it to a bright cherry red and laying it on the anvil, hold the tool about half an inch above it. Hold by the edges as shown in Fig. 72, if possible. When the heat from the metal has raised the tool to the desired temperature as indicated by the color, plunge it into the bath of water or oil. Do not plunge it in flatwise as held in Fig. 72. The cooling of the under side of

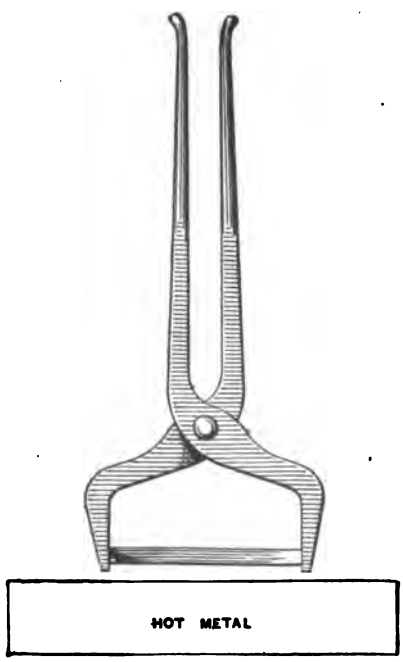


Fig. 72.

the tool before the upper will cause warping. Put the tool into the bath edgewise.

Another method of heating large wood working tools, such as saw plates and the like, is to submerge them in a bath of molten lead. This communicates an absolutely even temperature to the plate. It also has the advantage that no overheating can occur. The color at which the desired temperature is attained for various classes of tools is given in "Metallurgy."

Annealing is a process of softening steel. It is done so that it may be easily worked with hand or machine tools. It is accomplished by slowly cooling from a red heat. The usual method is to heat the piece red hot and then bury in lime or ashes. It is allowed to remain there until it is thoroughly cold. Twelve hours should be allowed for this work. For this purpose lime is better than ashes, as it is a poorer conductor of heat; hence the piece cools more slowly.

Another and quicker way of annealing is by the water method. The steel is heated to a cherry red and allowed to cool in a dark place until the red just disappears. It is then quickly plunged into cold water. This method should never be used when there is time to wait for the other.

Hardening and Annealing Brass. The process of hardening and annealing brass is exactly the reverse of that used with steel. Brass is hardened when it is heated and allowed to cool slowly; it is softened or annealed when heated and cooled suddenly. When annealing brass, care should be taken that it is evenly heated throughout and that it is evenly cooled.

Casehardening is the process of making a hardened steel case around a piece of iron. To do this the outer shell of the iron is converted into steel. The depth to which this conversion takes place varies from $\frac{1}{64}$ to $\frac{1}{32}$ inch. It depends upon the temperature to which the piece is subjected and the time during which the heat is continued. There are two methods of doing this work; the prussiate of potash and the box methods. The former is the more rapid; the latter the more reliable.

In casehardening with prussiate of potash, crush the material to a very fine powder. Then heat the steel to a red heat and

apply the powdered chemical to the surface to be hardened. The powder may be sprinkled on with a spoon and then rubbed over the surface with the back of the same. The iron must be hot enough so that the potash will melt and run freely. If, during the process, the iron cools so that the potash is not kept hot, it must be put back into the fire and again brought to a red heat. It is then cooled in cold water. This process makes a very hard case: one that cannot be touched with a file. It is, however, expensive. Therefore, it is not used where a large number of pieces are to be hardened. Neither is it suited for surfaces that are large or irregular in form. When hardening with prussiate of potash the heat decomposes it and the contained carbon unites with the iron. This forms a steel which in turn is hardened when it is suddenly cooled.

When a number of pieces or one single large piece is to be hardened, the box process should be used. This is a simpler and safer method. It is more easily executed and there is not the same danger of excessive warping as in the first described process. More or less warping, however, does occur whenever a piece of iron is casehardened.

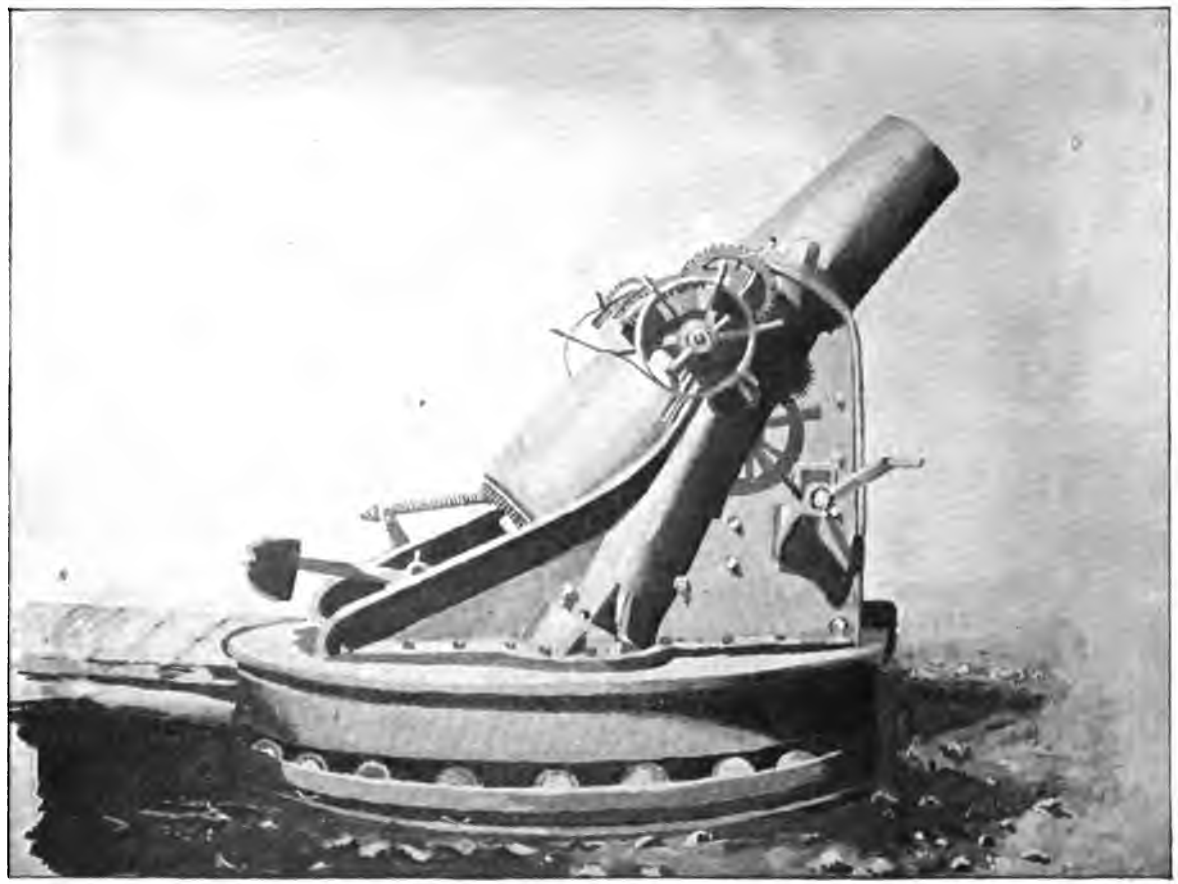
In the box process of casehardening, the pieces are packed in a box with the hardening material. The box should be of wrought or cast iron, preferably the former It should be of such size that all of the pieces may be packed without any of them touching the top, bottom or sides. In packing, first put a layer of the hardening material in the bottom. Next put in a layer of pieces to be hardened and pack the hardening material about and over them, ramming it down. Then put in another layer of pieces and pack in the same way. Continue until the box is filled. Fasten on the cover and fill all openings with fire clay so that the box is absolutely air tight. Now set the box and its contents in a furnace where it will be subjected to an even temperature. Raise it gradually to a bright cherry red and keep it in that condition for twenty-four hours. At the end of that time, remove it from the fire, and upon opening, cool the contents in cold water.

When the pieces are taken from the water they will be found quite hard and slightly warped. They may be straightened by springing them in a press.

In this work care should be taken to place the largest articles at the bottom of the box. They should all be so packed that as they settle during the process, they will be so held that one piece does not bear unnecessarily upon another and thus cause a needless amount of warping. When cooling, put the pieces in edgewise so that the cooling may be uniform and the amount of warping made as small as possible.

Various materials are used to assist in hardening. The most common and the one that is the cleanest and least offensive is bone dust. There are a number of compounds upon the market, which are all prepared and ready for use. These usually have bone dust as a base with other ingredients added. It is better and cheaper to buy these preparations than it is to attempt to make the mixture. Excellent results can be obtained from them. Where it is desired to do casehardening, and bone dust is not available, other materials may be used. Hoofs, old leather, salt and urine make an excellent casehardening mixture. To use these materials, cut the leather and hoofs into pieces of from $\frac{1}{2}$ inch to 1 inch in largest dimensions. A satisfactory proportion will be 20 pounds of old leather, 15 pounds of hoofs, 4 pounds of salt, to which a gallon of urine may be added after the packing is completed.

Brazing. Closely allied to welding is a method of uniting iron and steel called brazing. By this means two pieces are soldered together by a brass alloy. It is used where the parts are so small or thin that they would be burned or wasted away, if they were to be raised to a welding heat. Brazing is also used where finished parts that must not be stretched or upset by hammering are to be joined. The method is very simple. The parts to be joined are made bright and cleaned of all acid or grease. Paint the parts with some flux, such as borax, and raise to the melting point of the brass. Sprinkle brass filings over the joint. The parts, to be joined, must be firmly fastened while being heated. The brass should contain enough zinc so that its melting point is well below that of the iron. It should melt when the iron or steel has come to a bright cherry red. The brass must melt thoroughly or it will not adhere to the metal. Be very careful not to get the iron too hot. The heating had best be done on a charcoal or anthracite fire. Soft coal can only be used where the greatest care is exer-



COAST-DEFENSE MORTOR, SHOWING MASSIVE STEEL CONSTRUCTION

cised. The presence of sulphur in this fuel gives very poor results.

A method that is much easier to handle is now in extensive use. A graphite crucible is used, in which a quantity of brass is melted. The parts to be brazed are brightened and fastened together in the usual manner. Then they are painted with a flux such as borax paste. The parts not to be joined are painted with an anti-flux. For this a special preparation of graphite made by the Dixon Crucible Co., will answer. When the brass has been melted and the parts prepared as directed, the latter are plunged into the molten metal and held there until they have risen to the temperature of the same. They are then taken out, wiped, and the superfluous metal filed away. This method is extensively used for brazing bicycle frames and in doing work of a similar character.

Hammers. We have up to this time dealt with those light forms of work that can be performed by hand. The greater portion of all forging work now done, both large and small, is performed with the aid of power driven machinery. The principal machines are hammers, punches and shears. In connection with these are the furnaces of special design for heating the metal.

Hammers are of three kinds commonly known as power, trip, and steam. The **trip hammer** is usually formed of a heavy beam carried on trunnions near one end. The long end of the beam is weighted with a heavy head. The hammer is raised by the action of the wiper of a cam which depresses the short arm. This raises the head. After the cam has turned so as to release the lug on the short arm, the head falls by gravity and strikes a blow upon the anvil.

The Power Hammer differs from the trip in that the speed of the head due to gravity is increased by the tension of a spring. In general form that illustrated by Fig. 73 resembles the trip. The power hammer possesses this advantage over the trip hammer, that the intensity of the blow can be varied at will. The blow of the trip hammer is always the same in intensity and is that due to gravity. It varies only in the rapidity of delivery. In a power hammer such as that shown in Fig. 73, the smith controls the intensity as well as the rapidity of the blows by a treadle. Power hammers are made of various sizes capable of doing a correspondingly wide range of work.

Steam Hammers have almost entirely supplanted trip hammers for heavy work. An ordinary form of steam hammer is shown in Fig. 74. Its essential parts are an inverted steam cylinder, to whose piston rod the hammer head is attached, and the frame for carrying the whole. The hammer is raised by admitting steam beneath the piston. The blow is dealt by exhausting the steam from beneath the piston and admitting it above the same.

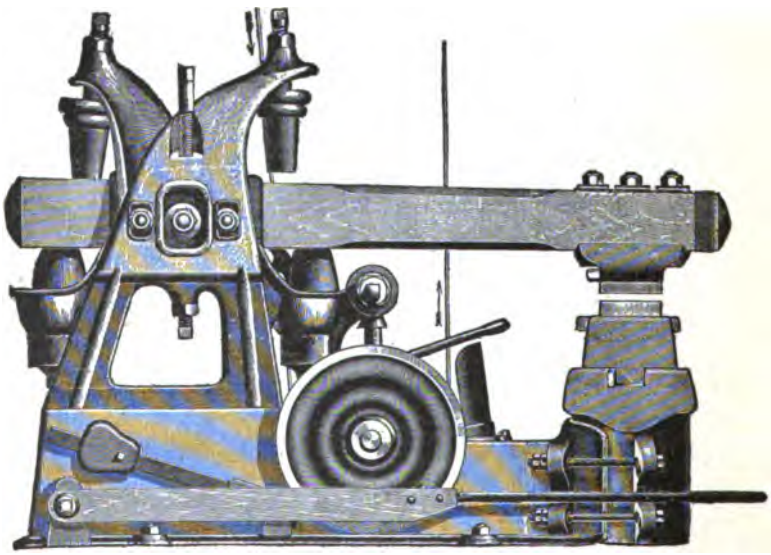


Fig. 78.

The head is thus accelerated by gravity and the pressure of steam above the piston. The valve gear is so arranged that the intensity of the blow may be varied by changing the amount of steam admitted to the piston on its downward stroke. The steam admitted below on the same stroke forms a cushion for the absorption of the momentum of the head. In this way the lightest of taps and the heaviest of blows can be delivered by the same hammer. These hammers are also made in a great variety of sizes. The head and piston of the lighter classes weigh but a few hundred pounds. The great hammer at the Bethlehem Iron Works, has these same parts one hundred and twenty-five tons in weight.

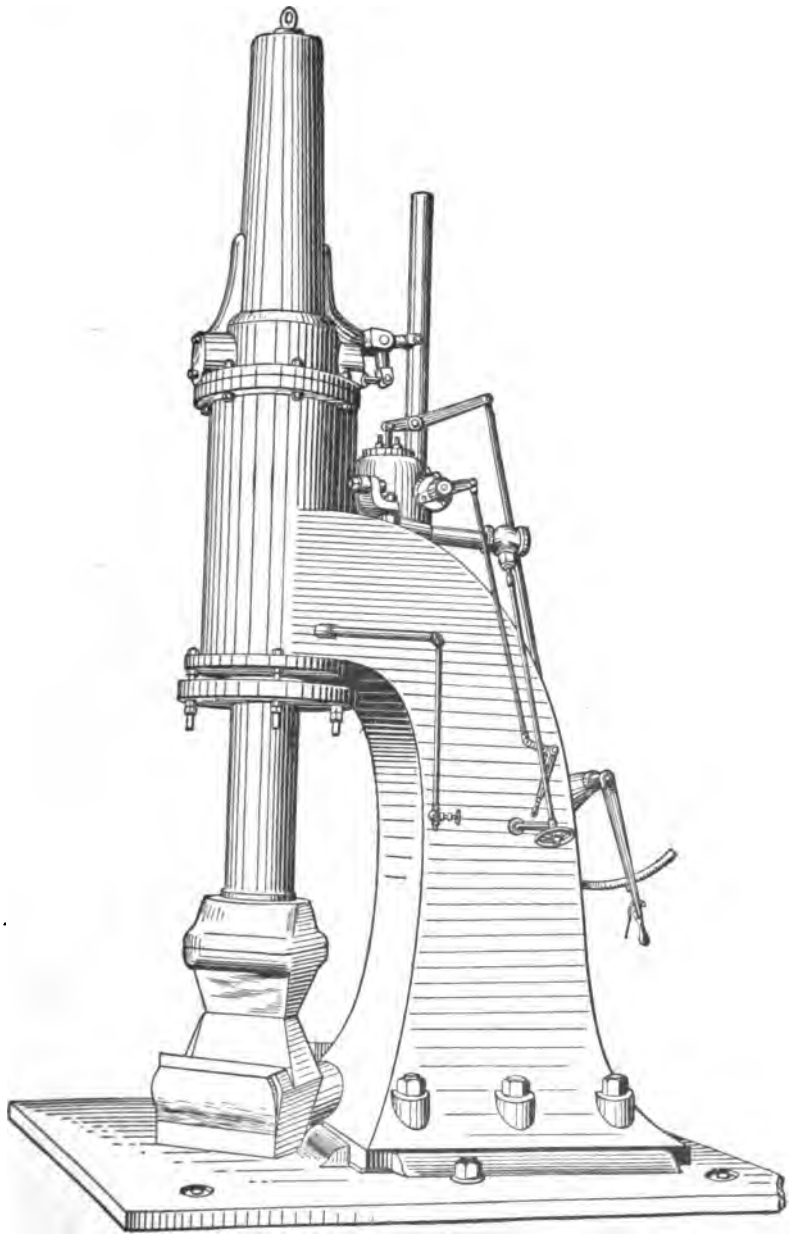


Fig. 74.

Punches are used for punching holes in metal and are of a great variety in size and design. Such a machine is shown in Fig. 75. A heavy fly wheel is kept in continuous motion by a belt of comparatively narrow width. The punch is operated directly by a

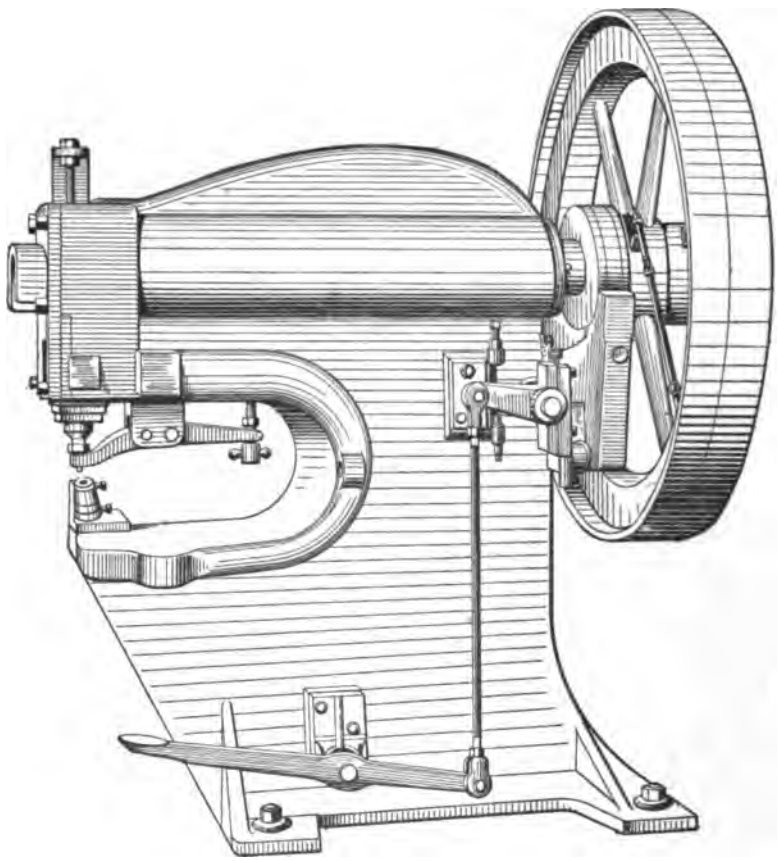


Fig. 75.

cam. The connection between the two is made by means of a clutch controlled by the operator. The punch is drawn to its highest point; the work is adjusted beneath it and the clutch connection made. The energy stored in the heavy fly wheel forces the punch down and through the metal. As the punch comes up out of the metal the clutch is thrown out of gear, and the fly wheel stores the energy needed for the next stroke of work.

Shears are for the purpose of cutting bars or plates. A convenient and powerful form of such a machine is shown in Fig. 76. It is operated on the same principle as the punch previously

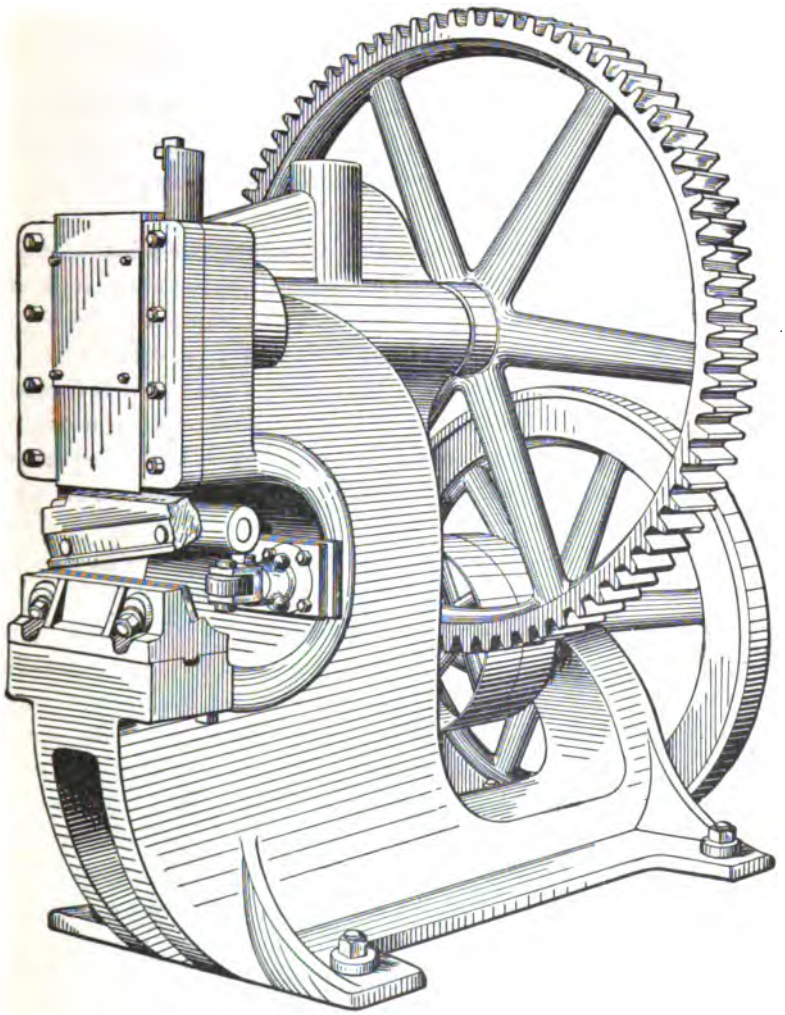


Fig. 76.

described. In the actual operation of the shears, however, the clutch is not usually thrown out of gear between each successive stroke of the cutter. Where metal is being cut to length in quan-

tities, a stop is usually bolted on, back of the cutter. The iron is pushed against this as the cutter rises and is cut to uniform lengths as it comes down. When shearing plates, the line of separation is first marked with chalk, a scriber or by center punch marks. The plate is then pushed between the cutter as the upper one rises and, being held there, is cut as it comes down.

There are many other machines of forms intended for special purposes, that are used in blacksmith shops. Among these may be mentioned drop forges, bending machines, presses, bolt headers, etc.

Drop Forges are used for quickly forming complicated shapes out of wrought iron or steel. They consist, as the name indicates, of a head that may be "dropped" from any desired height upon the piece to be shaped. The head of the drop and the anvil are in the form of dies. As they come together the metal is forced to flow so as to fill the interstices and thus take on the form desired. In drop forging the metal must be heated to a high temperature so as to be in a soft and plastic condition. A light straw color answers for most work.

Bending Machines are of great varieties and are used where certain shapes are to be duplicated in quantities.

Presses serve the same purpose as drop forges. They do the work more slowly, however. The class of work is, in some respects, the same. The principal difference lies in peculiarities of shape that require different time intervals for the flow of the metal. Where the shape is such that the metal must move slowly in order to acquire its new shape or fill the die, the press should be used.

Bolt Headers are really upsetting machines that form the heads of bolts upon straight rods. Owing to the rapidity with which they do their work, they are invariably used for manufacturing bolts in quantities.

Reverberatory Furnaces. It has been shown that for light work in the blacksmith shop the open fire either of anthracite or bituminous coal will give satisfactory results. In both of these cases the metal to be heated is in direct contact with the fuel. The same is true in the case of the cupola where iron is melted as shown in "Foundry Work." A reverberatory or air furnace is "a furnace in which ore, metal or other material is exposed to the

action of flame, but not to the contact of burning fuel. The flame passes over a bridge and then downward upon the material spread upon the hearth." Such furnaces are extensively used in shops where heavy work is being executed. They are also used for melting iron or other metals. For this purpose, however, they are not economical since they require about twice as much fuel as that used in the cupola for the production of good hot iron. To be effective the flame must be made to *reverberate* from the low roof of the furnace down upon the hearth and work. The form of the roof and the velocity of the currents determines the hottest part of the furnace.

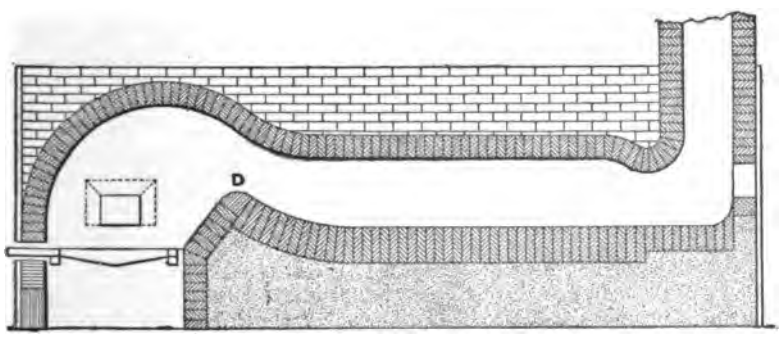


Fig. 77.

A common form of reverberatory furnace is shown in Fig. 77. The whole is lined with fire brick from the top of the grates to the top of the stack. The fuel is burned in a fire box separated from the heating portion of the furnace by a low bridge wall D. Access to the grate is obtained by suitable doors both above and below. When in service both doors are tightly closed and a strong forced draft is admitted to the ash pit. Beyond the bridge wall is the furnace proper. This usually consists of a low chamber with a level floor. Like the fire box it is completely lined with a thick wall of fire brick. Access is obtained to this chamber through a vertically sliding door as shown in the front elevation of the furnace, Fig. 78. These doors are also lined with fire brick and are usually suspended from chains. These pass over pulleys, and have counter balancing weights at the other end.

The operation of the furnace is exceedingly simple. After

the fuel has been charged upon the grates, the ash pit and furnace doors are closed ; the material to be heated is put upon the floor of the chamber ; the doors are closed and the draft admitted to the ash pit. The thick walls which surround the furnace prevent radiation of its heat. The fire brick are, therefore, heated to incandescence and the hot gases sweep through the chamber. The flow of the gases is usually checked by a choke damper on top of the stack.

The outer form of these furnaces is usually rectangular. Its

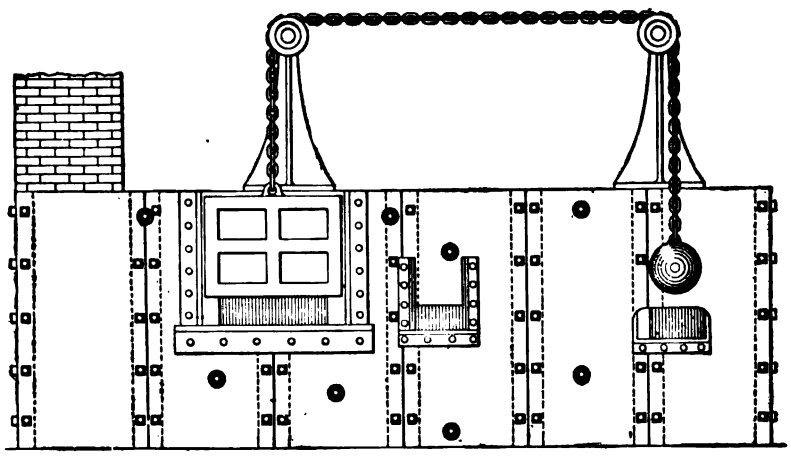


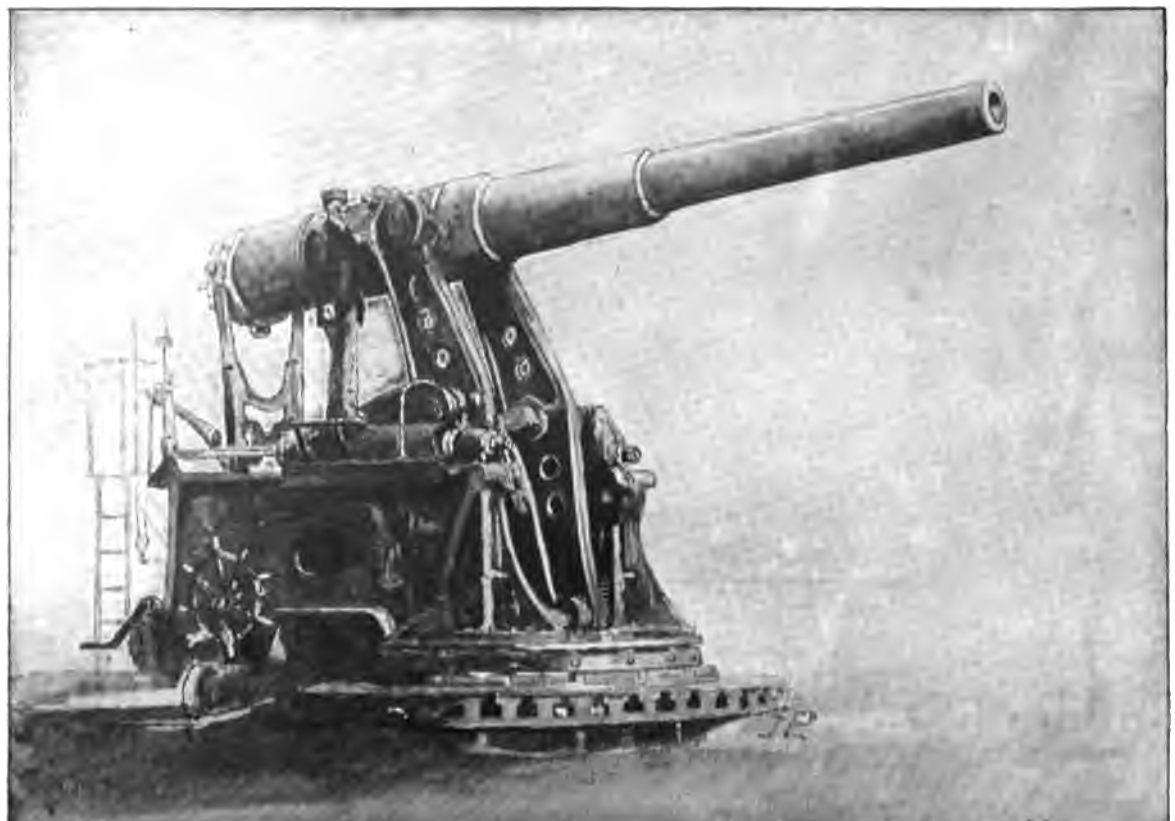
Fig. 78.

brick walls are tied together by stay rods to prevent bulging and the corners are protected by angle irons.

The selection of the fuel is an important matter in the operation of these furnaces. Experiments have been made with almost every kind of fuel. That now universally used is a soft bituminous coal that will not cake.

Steam or power hammers are always used in connection with these furnaces. The work is too large and heavy for manipulation by hand hammers.

An ordinary class of work done with them is the welding of slabs from small pieces of scrap. To do this a rough pine board about 12 inches wide and from 15 to 18 inches long is used. On it is neatly piled about 200 pounds of small scrap pieces. This material is then bound to the boards by wires, and the whole is



VIEW OF DISAPPEARING COAST-DEFENCE GUN, SHOWING LARGE FORGINGS

placed upon the hearth of the furnace. It is allowed to remain until the whole mass is at a welding heat. When in this condition, the plastic surfaces of the pieces serve to stick them together, so that the whole mass can be handled as a single unit by the tongs. The board, of course, burns away leaving the metal on the hearth. The metal is then lifted out and placed under the steam hammer. A few light blows serve to do the welding. After this heavier blows are struck and the mass is hammered into any shape that may be desired. Usually this first hammering gives it the form of a slab. Slabs thus made are cut up and again welded to form the metal for the final shape.

In the piling of the metal upon the board or *shingle*, as it is called, great care should be exercised. Iron and steel should not be piled together. Rusty metal should be cleaned before being put in the pile. Large air spaces between the pieces should be avoided. The whole mass should be packed together as compactly as possible. It will improve the quality of the slab if the pieces are laid upon the shingle with the grain of the metal running in the same direction. This is, however, very difficult or quite impossible to accomplish.

The handling of heavy work under the hammer varies somewhat from the method employed with the light work previously described. The heavy work is all supported and moved by cranes. The ordinary method is to suspend the piece by an endless chain from a point near its center of gravity as shown in Fig. 79. This endless chain is, in turn, carried by a sheave that may be raised or lowered by the mechanism of the crane. Such a suspension reduces the labor of balancing to a minimum and permits the work being turned to suit the blows of the hammer.

If the work is so large that only a portion of it is heated at one time, it may be grasped and manipulated from the cold sections. Usually a cross-lever is bolted to such pieces, thus adding to the leverage and facilitating turning. Where the whole piece is hot it may be held by tongs of a suitable size or shape. Such tongs are commonly made with crossbars to afford the necessary leverage for turning. Sometimes the tongs are dispensed with and a *porter bar* is used. Such a bar is welded to the piece being

worked to serve as a handle in its manipulation. It is cut off when the work of forging has been completed.

Connecting rods. In every shop where steam engines are manufactured the smith is called upon to forge the connecting rods. These are of great variety in size as well as in the shape of the stub ends. They are preferably forged of a single piece; but may be made from two or three. When of two pieces, the stub ends and one-half the rod are made in one piece with the weld in the center. When of three pieces each stub end and center of the rod is forged separately and then welded together. The form of the stub ends varies with the method used in fastening the brasses in position.

Fig. 79.

In order to forge a connecting rod of moderate dimensions, proceed as follows: Let us consider a rod having flat stub ends suited for brasses fitted with straps and keys. A block is first hammered down to a sectional area approximating that of the stub ends. It is then fullered out at H H (Fig. 80). After this has been done the central portion of the rod is drawn out to the diameter and length desired. The finished forging is shown in Fig. 81. Special care is required in the calculation of the weight of the rod's central portion: Also in the determination of weight for the corresponding section of the block and the proper location of the fuller marks H H. Unless these are properly located the proper weight or length of the rod center will not be obtained.

Shafts. The forging of shafts for steam vessels is an important piece of work and demands close attention to every detail. A most important thing for the smith to know before beginning work is the location of the bearings. He should then select his material and put it together in such a manner that no joints or welds shall occur at these points. The iron selected should be of new puddled metal, or if of steel, from an ingot newly made. If the latter is used the portion for the shaft should be cut from the lower end of the ingot. This avoids the laminations due to the

piping that usually occurs in the upper portions of all large ingots. Where steel of this character is used the work is simplified by the fact that it consists of drawing the ingot down to the desired diameter and length. When iron is used the first pile built up should be about three feet long, bound together at the ends with soft iron binders and with a porter bar set in at one end. If the furnace is large enough, the whole of the pile may be heated at once. If not, then a sufficient length to reach beyond the first bearing is welded. Three piles of this sort will suffice for a shaft 12 feet long. If the bearings are at or near the ends, this will put

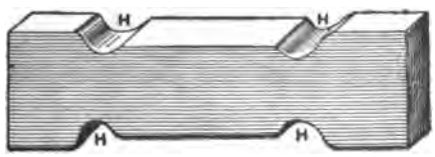


Fig. 80.

Fig. 81.

the welds in the central section. A suitable form of scarfing for the weld of such a shaft is that shown in Fig. 51. It is best when welding such a piece to close the joint by driving the pieces endwise. Then reheat the whole and finish the weld under the steam hammer in the ordinary manner. It is important, however, to forge the whole shaft, if possible, of one large piece. This avoids all necessity for any welds. The progressive appearances of such a shaft from the rough piece to the finished product are shown in Fig. 82. In this, A is the fagot that is first heated and to which the porter bar *a* has been welded. B represents the piece after the first hammering. It has been reduced in section in the center and made round. The ragged ends are still left in an enlarged shape. C shows the results of further hammering with a portion of the enlarged ends worked down into the body of the shaft. D illus-

trates the completed shaft with the crop ends cut off, the ends smooth and the whole ready for the machine shop.

The working down of such a shaft as this requires constant care during each step of the process. In the first place the heating must receive close attention. The metal should be heated to a dark straw color. This should be done slowly. If the metal is taken out of the furnace after a too rapid heating, it will be found that the center is at a much lower temperature than the outside. The result of a blow delivered to metal in such a condition will

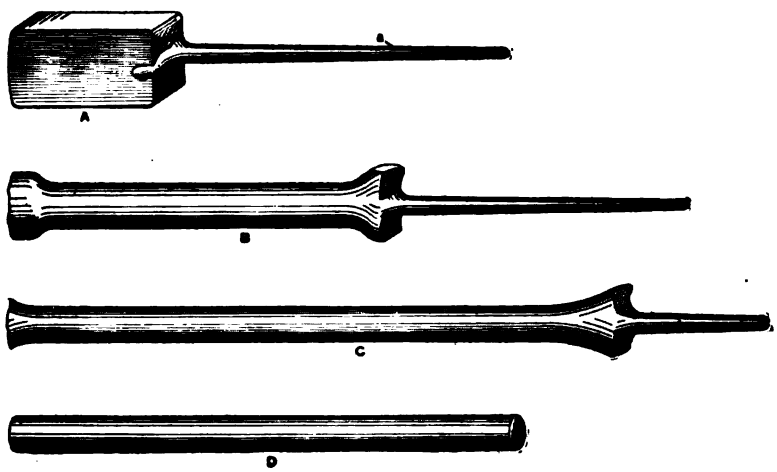


Fig. 82.

cause the outside to flow over the cooler core. Such a movement will be apt to cause the metal to crack and leave cold-shuts in the body of the shaft. A *cold-shut* is a crack or space over whose surface the metal is not united. They usually occur where an imperfect weld has been formed. The action above described may produce a condition resembling a cold-shut.

While the metal is at such high temperatures, scale forms with great rapidity. Scale, as already stated, is an oxide of iron. It can usually be brushed from the surface of the metal with perfect ease. During the process of hammering, a man should be stationed at the hammer with a longhandled brush with which he should remove the scale as rapidly as it is formed. If it is allowed

to remain upon this soft and plastic material, the hammer is a imbed it in the body of the metal. Succeeding blows may c the metal to flow over it, so that cold-shuts are formed.

When possible, the whole piece should be heated in the nace. Under these circumstances the hammering should be the whole surface and not confined to any one place. If the is evenly distributed, the metal flows evenly, and there ar weaknesses developed by distortion. But if, on the other h an excessive reduction is made at any one point, the hamme that must afterwards be done on the untouched section will c a weakness, due to a distortion of the metal. If such ham ing is done at the same heat the metal in the larger is worked lower temperature than in the first section. If the piec reheated, the smaller section will be raised to a higher tem ture than the larger and the metal at the junction of the two probably be weakened by distortion and a flow at such une temperatures. In many cases the furnace can heat but one at a time. When working metal heated in this manner, on small amount of hammering should be done each time. The should be reduced gradually, first at one end and then at the o This will prevent the formation of deep shoulders and the c quent weakening of the shaft at that point. It also avoids wide variation in the temperatures for the different sections.

We have seen that, at high temperatures, the formati scale is very rapid. When of a straw or light red color, the forms in flakes that may be easily brushed away. It is also and heavy. During the early stages of the forging the tem ture of a heavy shaft should not be allowed to fall below a red. As soon as it comes down to this point hammering sh cease and the piece be put back into the furnace for rehea During this early period, it is therefore, quite sufficient to k the scale away as previously directed. As the shaft appro completion, it is however, desirable to do the finishing work lower temperature. The formation of scale then becomes tro some, as it is more and more adhesive. If allowed to remain the metal it may so cover the latter with an opaque coating the piece will appear black and cold, whereas, it may actuall at a light red heat. The adhesion of the scale prevents it

being brushed away. It is, therefore, customary to turn a small stream of cold water upon the metal during the last or finishing hammering. This treatment loosens the scale, and is continued until the metal has cooled to a dark red, when the final coating of scale will form. This completely encases the body metal and serves as a tolerably efficient protection against rust.

The metal should be worked until it has been cooled to a dark red. There is a two-fold object in this. The metal is thoroughly compact and the scale is of the dark blue color that affords the most efficient protection. Care should, however, be exercised that the hammering is not prolonged until the temperature is too low. Great injury may be done to metal if this occurs. This is especially true of steel. After the red has disappeared the metal comes into what is known as the critical temperature, noticeable from the blue color. As an example of the effect of this blue temperature, which ranges from about 550° to 800° Fahr., that of boiler steel may be cited. It should be possible to bend a plate of good boiler steel double either when cold or at a red heat, without having it show any crack or flaw. If, however, an attempt is made to bend the same piece of steel when it is at a blue heat, it will crack at an angle of from 90° to 120°. Therefore steel should not be worked below a dull red heat.

The quality of a forging depends to a great extent upon the amount of work that is put upon it. Two pieces of metal may have exactly the same chemical properties and yet be entirely different in their physical characteristics. If one is rapidly forged in a single heat and at high temperature down to the finished size, it will be much weaker than another where the work has been done more slowly and by repeated heating. The work done on the metal condenses the material, adds to its strength and increases its wearing qualities. It is the investment of labor for which durability and strength are returned as a dividend.

Crank Axles. An important piece of work is the making of crank axles for steam engines either for marine or stationary service. In order to forge a small two-arm crank-shaft like that shown in Fig. 83, a soft, tenacious piece of metal should be selected, one that can be easily upset. It is well to use iron whose diameter is equal to that of the finished shaft. If the shaft is to be

very long it will be well to forge the crank separately and then weld it in position. First determine the position of the crank-pin by adding the length of one arm to one end of the shaft. This gives the commencement of the crank-pin. From this point to a short distance beyond the other end of the crank-pin the metal should first be upset. This upsetting should be done at or near a welding heat and should make the bar about one-quarter larger than the original diameter. The work must next be upset at the base of each arm. These points are located on each side of the crank-pin at distances equal to the length of the arm. The upsetting at these points should be such as to produce about the same increase of diameter as before. This will leave the piece in the condition

Fig. 83.

Fig. 84.

shown by Fig. 84. After the upsetting the first bending should be done at one end of the intended crank-pin; the next should be at the other end. If, however, the pin is to be very short, a single bend may be used, leaving the piece in the form of a longlegged U. During the whole of this work the diameter of the crank-pin is of far less importance than the length. The latter should be so adjusted that the metal in the arms at each end will just clean up in the lathe, and leave the pin of the proper length. The only precaution necessary in regard to the diameter is that it shall be large enough. If, when the bends have been made it is found that the pin is too short, it may be stretched with the fullers. If it is too long, it should be reheated and upset.

After the length of the pin has been properly formed the throw is made by bending back the two ends. This should be done when the pin is cool enough to retain its shape while the work is being done on the adjoining parts. It is well to cool the pin in water before doing the work. When this bending is

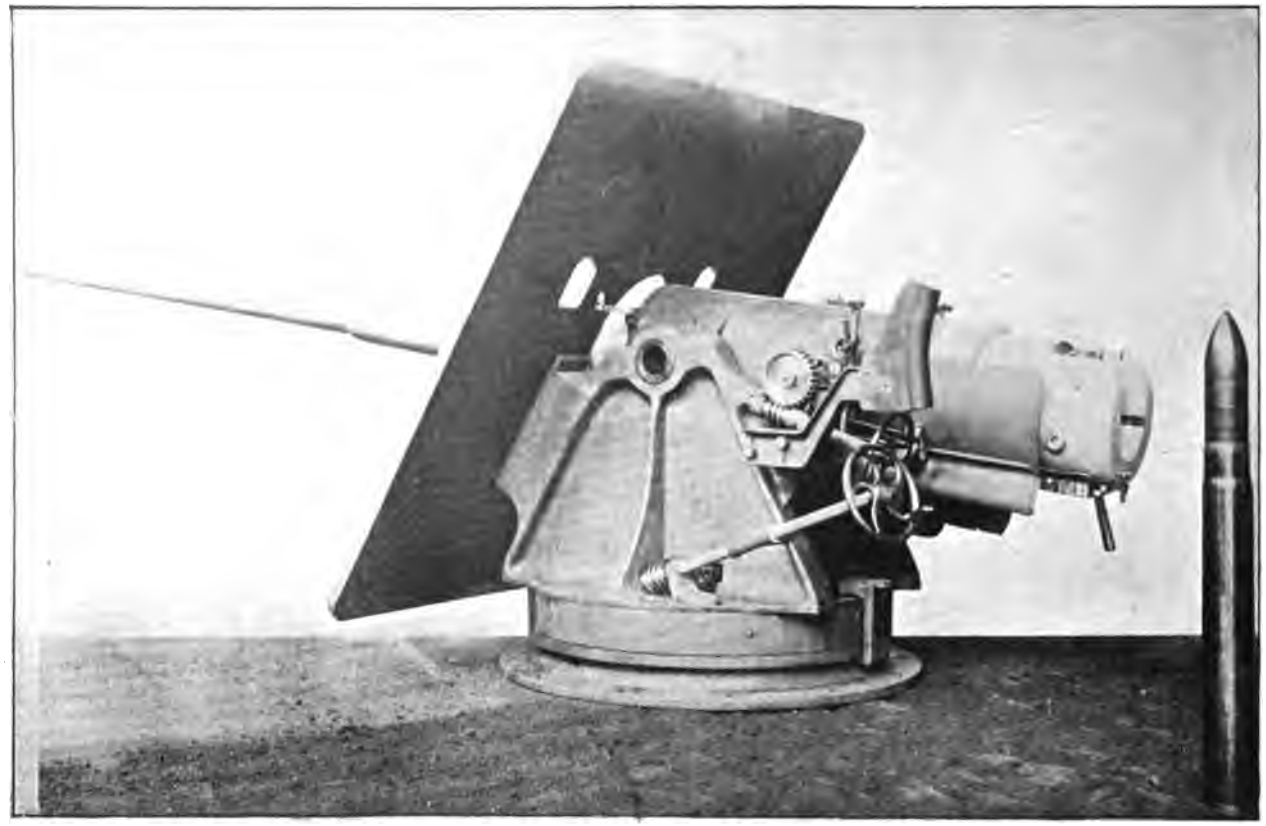
being done the length of the heated portion of the shaft should be equal to the length of the curve desired. If the bend is not made in the proper place the throw of the crank will be either too long or too short. The work must then be reheated and the arm either upset or drawn to the correct length.

When the crank has been formed in this way, it remains to adjust the two sections of the shaft so that they will be in alignment with each other. This can be done by laying a straight-edge along the two parts. Then the ends are cut to the proper length and the shaft is ready for the machine shop.

Where large numbers of such shafts are required the work is accomplished under a press with dies.

Heavy cranks are either built up or made in one piece. Where they are built up, the shaft, each arm, and the crank-pin are forged separately. Where made in one piece, it is common practice to make the arms and pin solid and cut out the gap in the machine shop. Sometimes the gap is partly formed by fullering between the arms. These are known as solid cranks. They may be made by using a heavy bar whose width is equal to the arm plus the shaft diameter. Or the crank boss may be formed by piling and welding to the shaft. The former method is preferable, as it avoids cutting an original length of shaft and puts a desired amount of work upon the shaft ends. The successive forms of such a shaft are shown at A, B and C of Fig. 85. In this figure A shows the original crank bar which is of rectangular section. The whole block is first heated in the reverberatory furnace and the fuller driven in at *a a*. When this has been done, the ends are drawn out and hammered into a circular section. Finally, in order to lessen the work in the machine shop the gap is partially fullered out as shown at C.

In the finishing of such a shaft the fuller should be used to form ample fillets between the shaft and the crank hump. The latter should also be subjected to some heavy hammering. For this reason it is well to select a bar of large cross-section so that even the crank may require considerable reduction in order to bring it to size. If little or no hammering is done on the crank that portion of the shaft will be the weakest. In reality it should be the strongest because it is subjected to the heaviest stresses. This



HOTCHKISS 55-POUNDER QUICK-FIRING GUN

is especially the case in marine engines where all of the work performed by the forward engines is carried back to the screw through the after cranks.

Miscellaneous Suggestions. In doing work in the blacksmith shop it must be constantly remembered that the work is larger at the time it is being manipulated than it will be when cool. Allowance must, therefore, always be made for shrinkage. As the pattern maker allows for the contraction of the molten metal to the cold casting, so the blacksmith must allow for the contraction of the hot iron or steel to the cold forging.

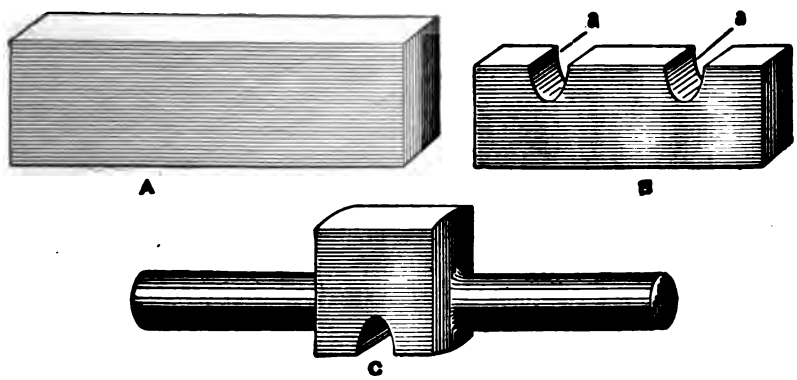


Fig. 85.

The temperatures of iron at the several colors, are as follows:

Iron, red in the dark	750° Fahr.
Iron, red in daylight	880° Fahr.
Iron, straw color	1150° Fahr.
Steel, welding heat	1350° Fahr.
Iron, welding heat	1700° Fahr.

From the above it will be seen that the temperature at which forgings are finished under the hammer, should be at about 900° Fahr. When these same forgings are cold their temperature will be from 60° to 70° Fahr. There is, therefore, a difference of at least, 840° between the working and the finished temperature. The expansion of iron may be taken to average about .00000648 of its length for each increase of one degree Fahrenheit in its temperature. Therefore, the difference between the length of a bar

of iron at 60° and at 900° is .0054 of its length when cold. Suppose then, we have the side rods of a locomotive to weld. If they are to be 9 feet long when finished, they must be 9 feet 0.58 inch long when at a red heat. This means that in the rough slightly more than $\frac{1}{2}$ inch must be allowed for contraction. If only a portion of the rod is heated the allowance is to be proportionately less.

The tempering of steel tools has already been discussed. In such work only a small portion of the metal needs to be tempered. Springs require a slightly different treatment. They must be tempered throughout their whole extent. The ordinary method of tempering a steel spring is to heat it to a cherry red and then cool it by plunging into a bath of oil. This treatment hardens the metal but does not give it the same degree as plunging into water. The reason is that the oil does not absorb the heat of the metal as rapidly as the water, with the result that the cooling takes place more slowly. Such treatment leaves the metal harder than in its annealed condition, and yet not as hard as when plunged into water. This intermediate condition is suitable for service as a spring. The best results can probably be obtained if whale oil is used for the bath.

SECTION 4.

MACHINE SHOP WORK.

MACHINE shop work is usually understood to include all cold metal work in which a portion of the metal is removed to make the piece of the required shape and size either by power-driven or hand tools. However, there are some branches of cold metal-work, such as sheet-iron work and coppersmithing, that are not included in machine shop work.

HAND-OPERATED TOOLS.

As the hand-operated tools are much simpler, and as the operations performed with them are in every case more typical, their description and use should precede that of power-driven tools. It should be clearly understood, however, that machine shop practice involves the use of both classes at the same time. Even hand tools are not used in the same order on different classes of work; it is, therefore, impossible to describe them in the order of use. Simplicity of construction and operation will be the guide for treatment in the following pages.

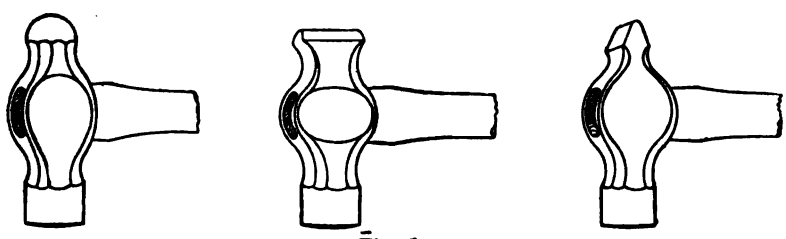


Fig. 1.

The machinist uses **hammers** of three shapes: ball pene, cross pene, and straight pene. See Fig. 1. The first named, the ball pene, is the most common; it varies in weight from four ounces to three pounds. The cross and straight pene hammers vary from four ounces to two pounds and are used principally in riveting. All hammers are made from a good grade of cast steel,

hardened, and drawn to a blue color at the eye and a dark straw on the face and pene. The eye is elliptical in shape, and the handle is fastened by driving wedges, either wood or iron, into the end of the handle, thus spreading it to fill the eye. The handle is of hard wood, preferably hickory, and of a length suited

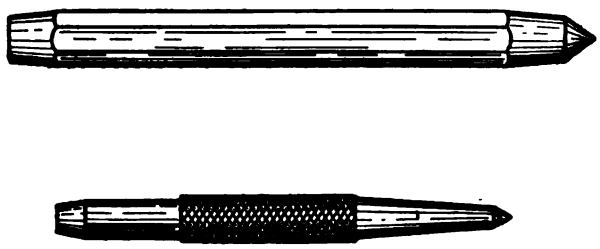


Fig. 2.

to the weight of the hammerhead. When the handle is properly inserted, the axis of the head stands at right angles to the axis of the handle.

Soft hammers are used for striking heavy blows where the steel hammer would bruise the metal or mar the surface. They are made of rawhide, copper, or Babbitt metal, and vary in weight from six ounces to six pounds. They are subject to rapid wear, but are indispensable in setting up and taking down machinery. Those of metal are so constructed that the soft metal can be re-cast in the handle.

Fig. 3.

The *prick punch*, Fig. 2, is made of cast steel with a hardened conical point of about 60 degrees. It is about 3½ inches long and ¼ inch in diameter. It is used for making very small holes at intervals of about ½ inch on a line.

The **center punch**, also shown in Fig. 2, is made of the same general appearance as the prick punch, but is about 5 inches long, ½ inch in diameter, and has a point of about 90 degrees. The principal use is to make center holes marking the centers on the ends of pieces to be turned.

Both prick punches and center punches are usually made of

hexagonal steel; but if round stock is used, the grip should be fluted or knurled to prevent slipping in the fingers.

The **scriber** or **scratch awl**, Fig. 3, is made in many forms, but consists essentially of a cast-steel rod about 8 inches long and $\frac{3}{16}$ inch in diameter, with a long, slender, hardened point at each end; frequently one point is bent at right angles to the shank. As the name indicates, this tool is used for marking lines on the surface of metal.

The **surface gauge** is used in laying out work for the bench, lathe, or planer. The ordinary form consists of a heavy base, an upright, and a scriber or scratch awl; the upright being firmly fastened to the base. In the universal gauge, the upright is pivoted at the base so that it may be used at any angle. In some forms the base is grooved in order that the gauge may be used on cylindrical work as well as on flat surfaces. See Fig. 4.

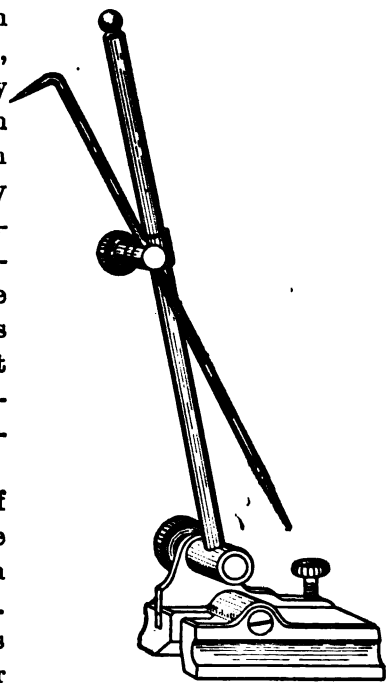


Fig. 4.

To use the gauge, the part of the work to be laid out must be prepared so that lines drawn on the surface will show distinctly. A rough or unfinished surface is covered with chalk, a finished or bright surface should be copper-plated by applying a thin coating of copper sulphate solution with a brush or a piece of waste. The work and gauge are then placed on a true surface and the scriber adjusted to the desired height. The line is drawn by moving the surface gauge along on the true surface, keeping the point in contact with the work. After scribing the lines, it is well to place light prick punch marks at frequent intervals along the lines, so that the position may be found if the chalk or copper sulphate becomes effaced.

The **straight edge** consists, in its simplest form, of a thin flat piece of steel, generally unhardened, with accurately finished straight edges. The very small sizes used in fine work are sometimes made with a hardened knife edge. A non-conducting handle is sometimes used with the small sizes to prevent distortion from the unequal heating due to handling. The short lengths used for ordinary shop purposes have one edge beveled, and are thick enough to avoid bending. See Fig. 5. The larger sizes, from three to ten feet or more in length, are usually made of cast iron with one finished edge. The metal is so distributed as to combine lightness with great rigidity, the tendency of the ends to drop being resisted by the truss-like form of the casting shown in Fig. 6. The flat form is used, in connection with the scriber, to draw accurate straight lines on plane surfaces. All styles are used to test the truth of plane sufaces by placing the straight edge on the surface to be tested in not less than the six positions shown in Fig. 7.

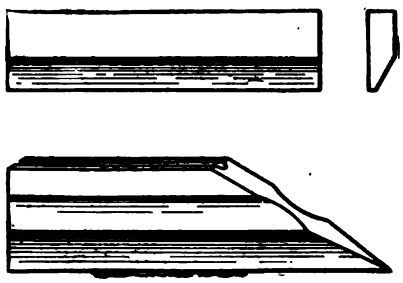


Fig. 5.

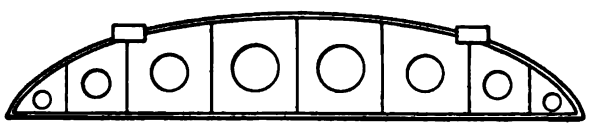


Fig. 6.

For drawing lines and laying off distances on curved surfaces, such as shafts, a combination of two straight edges, or a straight edge and a rule, is used. This is often called a *key seat rule* because its chief use is laying out keys on shafts. However, many machinists call it a "box-rule." It is usually made in one piece, although some manufacturers provide clamps by which the two separate pieces are held at right angles to one another. A more simple combination is shown in Fig. 8, the second scale being represented by two special clamps.

The simplest form of square, called the *flat square* (Fig. 9), is a combination of two straight edges at right angles. This is a useful form where the square is laid on the work. One blade

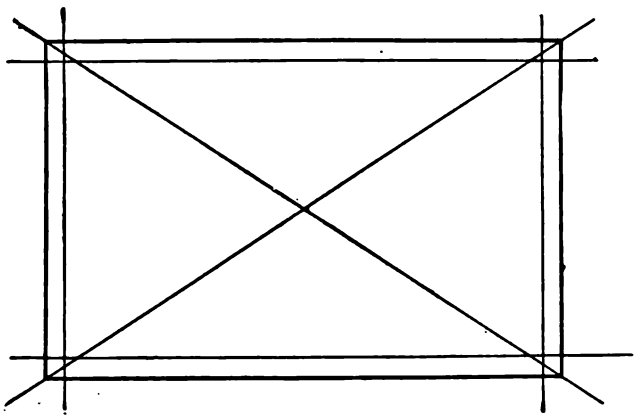


Fig. 7.

is usually graduated on the inner edge, and the other on the outer edge. The flat square is not hardened.

The **try square,** shown in Fig. 10, consists of a beam and a blade at right angles. The beam is much thicker than the

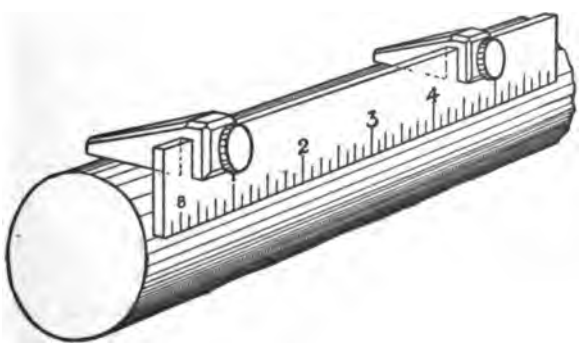


Fig. 8.

blade and somewhat shorter. Try squares are made both unhardened and hardened. The unhardened form has graduations on one edge, and is called the graduated try square. The hardened type always has a hardened blade, sometimes a hardened beam as well, and is not graduated.

The try square is used as a guide to draw lines at right angles to each other and to given surfaces; to erect and test perpendiculars to plane surfaces; to test the truth of a given surface at right angles to another surface; in short, it is used wherever an accurate measurement of 90° is required. When used for testing the relation of two surfaces, the beam is pressed closely against the correct surface, and the blade brought carefully down to the

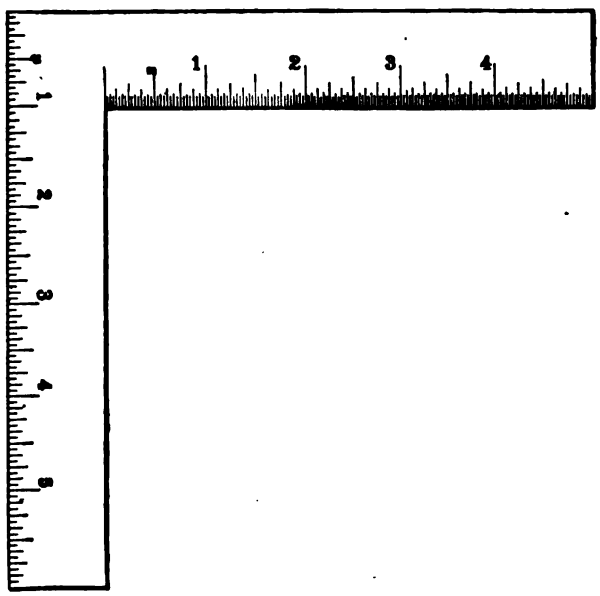


Fig. 9.

surface under consideration. This does not prove more than that a line at the particular point tested is or is not at right angles to the true surface. By using the blade as a straight edge parallel to the true surface, errors in that direction may be corrected and the surface be made plane.

In many cases it is necessary to test the relation of lines and surfaces which are not at right angles to each other. For this purpose a **bevel** is used in which what corresponds to the blade of the square is made adjustable. Its construction is seen in Fig. 11, and its use is similar to that of the square.

The bevel can be adjusted only by direct application to lines or surfaces having the proper angular relation. It often happens that such adjustment is not feasible, and therefore a registering device, in the form of a graduated arc, is applied to the bevel, making what is known as a **protractor**, shown in Fig. 13. This tool can be used to find the angular relation in degrees or to produce that relation by setting to the proper point on the graduated arc.

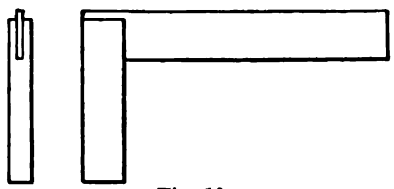


Fig. 10.

As the center of a circle is found at the intersection of any two diameters, an instrument for readily finding that point is a great convenience. In Fig. 12 is shown a combination of straight edge and square called a **center square**, which accomplishes this

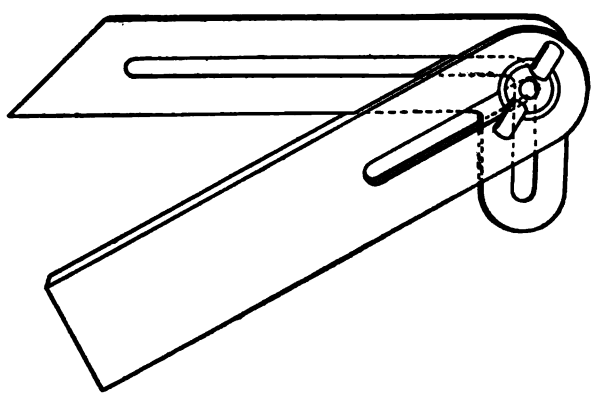


Fig. 11.

result. As one edge of the rule bisects the angle of the square, it is evident that a line drawn by that edge passes through the center of any circular piece to which the square is applied. Centering the ends of round bars or circular work of any kind is the principal use of this tool.

The center square, bevel, and protractor are furnished in a combination set as shown in Fig. 14. The ability to change the length of the blade is one of the great benefits of this construction.

MEASURING TOOLS

The testing tools thus far described are used for comparing the angular relation of lines and surfaces, and may be called tools for angular measurement. We now turn to the consideration of instruments for measuring distances and sizes, or tools for linear measurement.

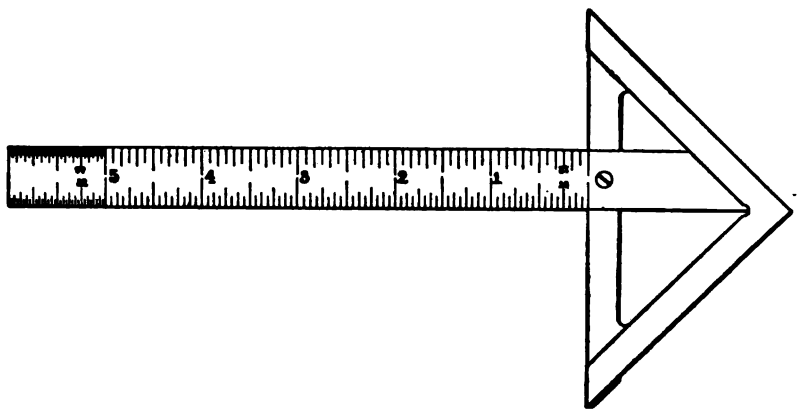


Fig. 12.

The most common tool for *linear measurements*, and one which hardly requires description, is the so called carpenter's or two-

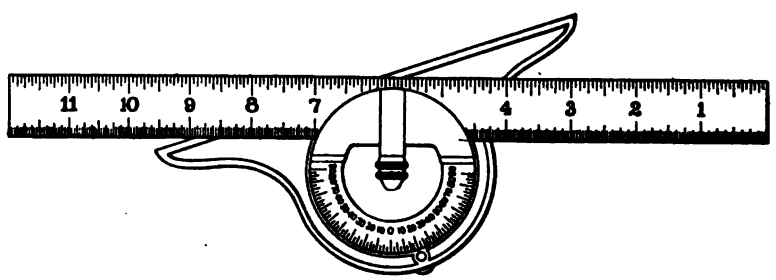


Fig. 13.

foot rule. This is very convenient for the machinist in making measurements which are not required to be very accurate. For

work of greater refinement, the **standard steel scale** (Fig. 15) is used. This is in reality a divided or graduated straight edge and, as such, forms a part of several tools already described. The most common form of steel scale is flat, varying from one to forty-

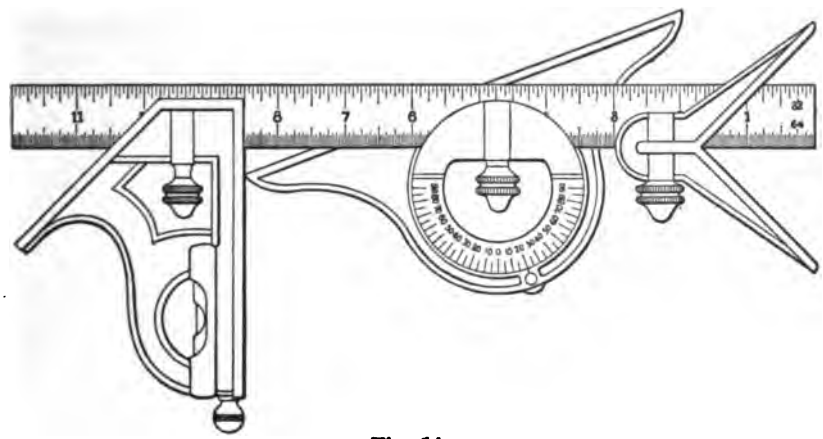


Fig. 14.

eight inches in length, and carefully hardened and ground. The graduations in the better class of scales are cut with a dividing engine, although the lines may be etched on the surface with a fair degree of accuracy. A thin and somewhat narrower form, called a flexible scale, is made in sizes from four to thirty-six inches. What are known as narrow scales are obtainable from

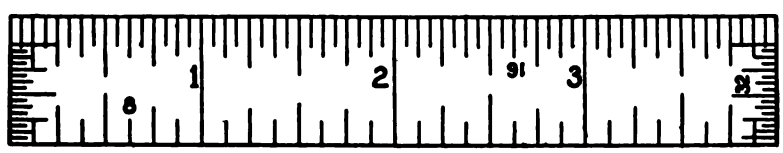


Fig. 15.

four to thirty-six inches, and are of great convenience in certain cases. Besides these shapes, square scales are made in sizes from three to six inches in length, and the triangular form varies in length from three to twelve inches. Steel scales with the English system of graduation can be obtained with the inches divided in eighths, sixteenths, thirty-seconds, sixty-fourths; twelfths,

twenty-fourths; tenths, twentieths, fiftieths, and hundredths. Special scales are made with graduations especially adapted to such uses as gear blank sizing, etc.

The ends of flat rules are sometimes graduated, making what might be called a very short rule with a handle. Flat rules are sometimes graduated with Metric divisions as fine as one millimeter, and from five centimeters to one meter in length.

For transferring and comparing distances, **dividers** are commonly used. They are classified according to the style of joint

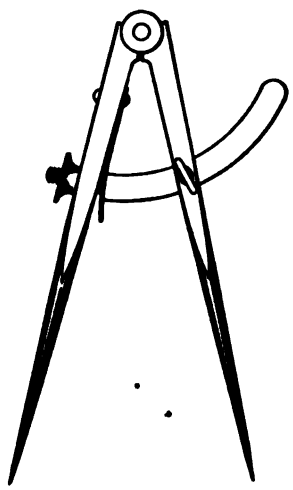


Fig. 16.

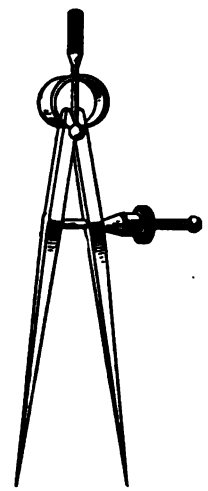


Fig. 17.

and the length of the leg. The most simple joint is the friction, and like all frictional devices, is hard to set accurately. Lock-joint dividers can be moved freely to approximately the right position, the joint locked, and the adjusting screw used for the final setting.

Wing dividers, Fig. 16, are of about the same construction as the lock joint, except that the fastening is made on the wing instead of at the pivot. The best of all forms has a spring adjustment as shown in Fig. 17. In this type, a spring tends to open the dividers, and the legs are closed against the spring by a nut working on a screw which is fastened to one leg and passes

freely through the other. The length of dividers varies from two and one-half to ten inches. The distance to which dividers can be opened is generally about equal to the length of the leg. For distances above ten inches, *trammel points*, diagram, Fig. 18, are convenient. They consist of hardened steel points attached to metal sockets, and can be used on rods of any length. One point may have a spring adjustment, and in that case can be set in the same manner as a pair of wing dividers.

Next in importance to the dividers as an adjustable distance gauge, are the **calipers.** Instead of having straight legs with

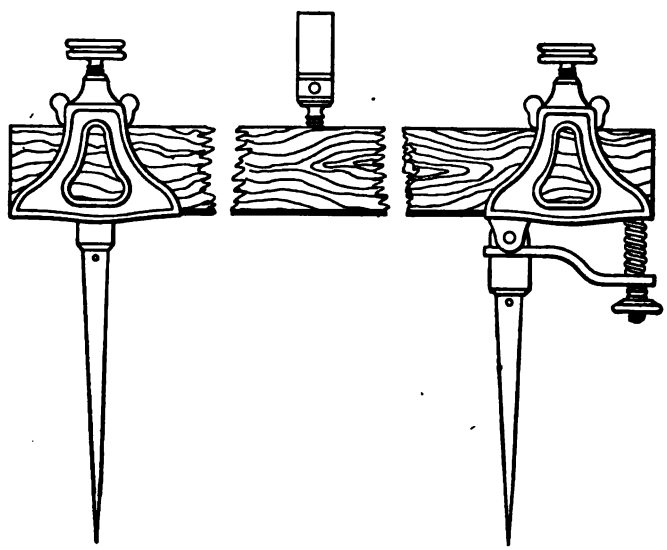


Fig. 18.

sharp points, caliper legs are bent and have blunt points. As distances are to be measured both outside and inside of solid bodies, we have outside and inside calipers. The legs of outside calipers have a large curvature so that the calipers may be passed over cylinders of their greatest capacity.

Inside calipers, Fig. 20, are more like dividers in general appearance, the ends being bent outward slightly and the points rounded. The same styles of joints used in dividers are used in calipers, and the size of calipers is also designated by the distance from the joint to the end of the leg. Spring calipers are made

in sizes from two and one-half to eight inches, while the other styles vary up to twenty-four inches.

As it is sometimes necessary to make measurements behind shoulders and in chambered cavities, where the ordinary calipers could not be removed after setting, it is necessary to have calipers so arranged that they may be set, changed to clear the obstruction, and then reset accurately in the first position. This is accomplished by **transfer calipers**, Fig. 19, in which one leg is temporarily fastened to a stub or false leg as shown. After set-

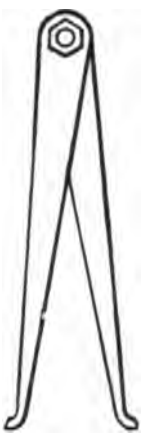


Fig. 20.

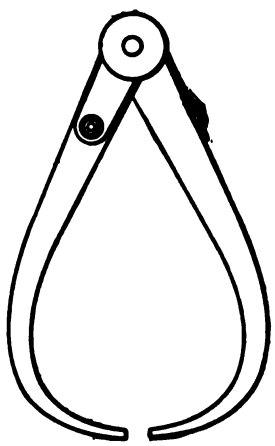


Fig. 19.

ting, this leg may be moved away from the stub, the calipers withdrawn, and the leg again placed in contact with the stub; the points will then be found to occupy the same position as when first set. Small curved legs may be used in place of points or trammels in calipering large objects.

Both dividers and calipers are usually set by means of a scale. In setting dividers, place one point in a graduation of the scale, and move the other until it falls easily into another graduation which gives the required distance. Outside calipers are often set by placing one leg against the end of the scale and moving the other until it is opposite the middle of the graduation giving the required length. As the graduations are not mathematical lines, but have an appreciable width, this last precaution is one of

great importance. Inside calipers are set by placing both the scale and caliper toe against a plane surface as shown in Fig. 21; the other toe is then set the same as the outside caliper.

Caliper legs are comparatively slender, are easily bent, and care must be taken in using them to see that the contact with the object being tested is very light. It is an easy matter to spring calipers of common sizes as much as one-sixteenth of an inch.

The **caliper square** is made by attaching a movable blade to the common square. In the ordinary forms it closely resembles a steel rule with two arms extending from it at right angles, one fixed near the end and the adjustable arm sliding along the scale with a clamping device for adjusting this movable arm. In order that the movable arm may be set accurately, caliper squares (Fig. 22), as at present constructed, have two clamps for the movable arm. The one carrying the thumb nut is to be first clamped in approximately the right position; the clamp on the movable arm being

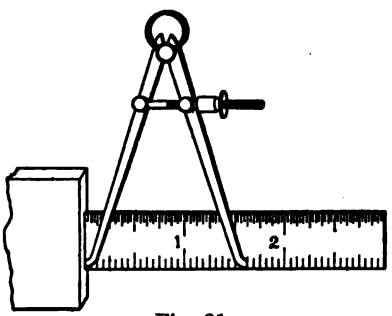


Fig. 21.

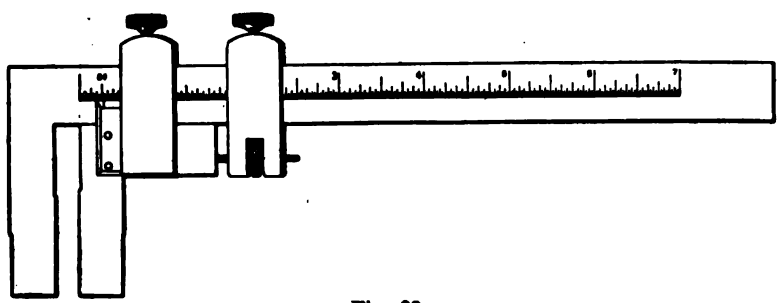


Fig. 22.

secured after the adjustment has been made by the nut. The sizes used vary from three inches up, and are limited only by the length of scales obtainable.

For measurements which are required to be more accurate than can be obtained by the preceding forms of calipering devices, the

micrometer caliper, Fig. 23, is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

It consists, essentially, of a crescent-shaped frame carrying a hardened steel anvil B at one end and a nut of fine pitch at the other; the axis of the nut being at right angles to the face of the anvil. The outside of the nut, A, forms a projection beyond

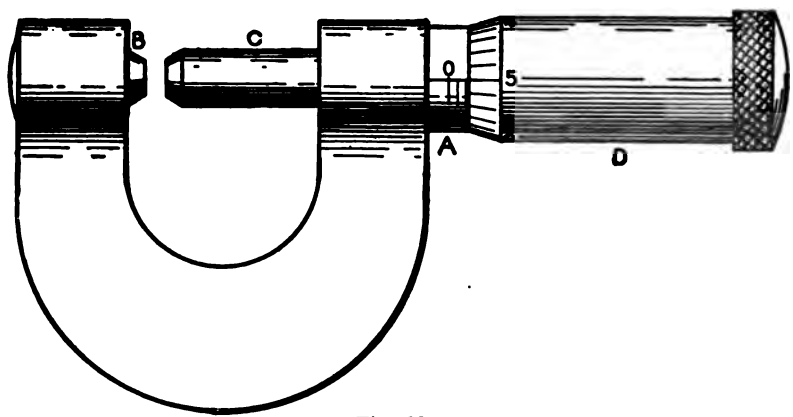


Fig. 23.

the crescent that is called the barrel. The measuring screw consists of a fine-pitched screw to fit the nut, combined with a measuring point C, having a face parallel with that of the anvil. Firmly attached to the outer end of this screw, is a thimble D, fitting closely over the barrel; the edge of this thimble is beveled so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel indicates a movement of the measuring point of one thousandth of an inch. For example: if the pitch of the measuring screw is one hundredth of an inch, there should be ten divisions on the

thimble; if one fiftieth of an inch, twenty divisions; if one fortieth of an inch, twenty-five divisions; if one twenty-fifth of an inch, forty divisions. Measuring screws having a pitch of one fortieth of an inch are commonly used, and every fourth division on the barrel lengthened and numbered to indicate tenths of an inch as shown in the figure.

In using the micrometer caliper, it should not be set at the size required and pushed over the work, but should be screwed down until the measuring point C and anvil B are in contact with the work; the size may then be read from the relation of the thimble to the reference line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble so that undue pressure cannot be exerted.

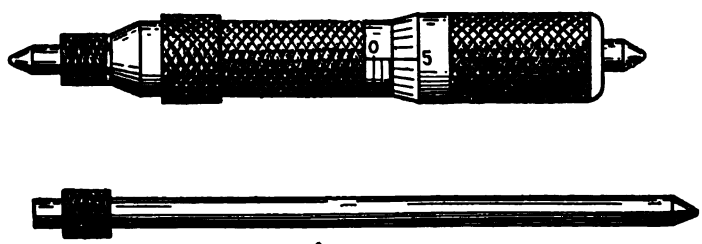


Fig. 24.

The micrometer caliper will not only indicate that the work is too large or too small, but will also show exactly the amount by which it differs from the desired measurement. This is a great improvement over the rigid form of calipers, and enables the workman to judge more accurately the progress of the work. This form of caliper is rapidly coming into favor in spite of its cost, and for this reason it has been described more at length than the common forms previously considered.

The range of motion of the measuring screw is usually limited to one inch. Various devices give the micrometer caliper a larger range of action. Micrometer calipers may now be purchased in combinations or sets giving a range from zero to twelve inches.

The application of the micrometer principle to inside meas-

urements is not in general use, but is easy to arrange, and makes a very simple instrument, as shown in Fig. 24. It consists of an ordinary micrometer head, except that the outer end of the thimble carries a contact point, attached to a measuring rod which may be of any length. Two inches is about the shortest distance that can be measured with this device, but there is hardly any limit in length, as the rigidity of the rod is easily provided for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement, and thus limits this form to about 12 inches, as above stated. The contact points in the outside type are parallel plane surfaces, and in the inside form are rounded points of small radius. Outside micrometers are pro-

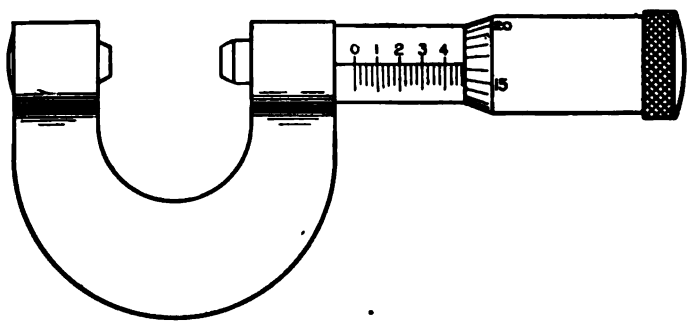


Fig. 25.

vided with contact points of varying forms for measuring paper, threads, walls of tubes, etc. The shapes for these purposes will not be shown, but may easily be imagined.

Reading the Micrometer. As stated above, the micrometer screw has 40 threads per inch and the thimble has 25 divisions on its circumference. The barrel is divided to correspond to the pitch of the screw with each fourth division numbered. In reading the indicated measurement, first note the highest number visible on the barrel, and call it hundreds of thousands or tenths. (In Fig. 25 it is 400 thousandths or .400.) Then read the short divisions on the barrel, calling the first division 25 thousandths (.025), the second 50 thousandths (.050), and the third 75 thousandths (.075). In this figure the third division is the last one visible. Now read the number indicated on the thimble; that is,

the number that has passed the line running lengthwise. In the figure it is 16; or $16\frac{1}{2}$ if the reading is to be finer than thousandths. Add this reading to the readings of the short divisions, thus: $75+16\frac{1}{2}=91\frac{1}{2}$; this is $.091\frac{1}{2}$. Adding the .400 to this we get $.491\frac{1}{2}$. This means that the distance from the anvil to the measuring-point is $\frac{4915}{10000}$ of an inch, or .4915 inch. If the micrometer caliper is a good one, we may be sure the distance is between .491 inch and .492 inch.

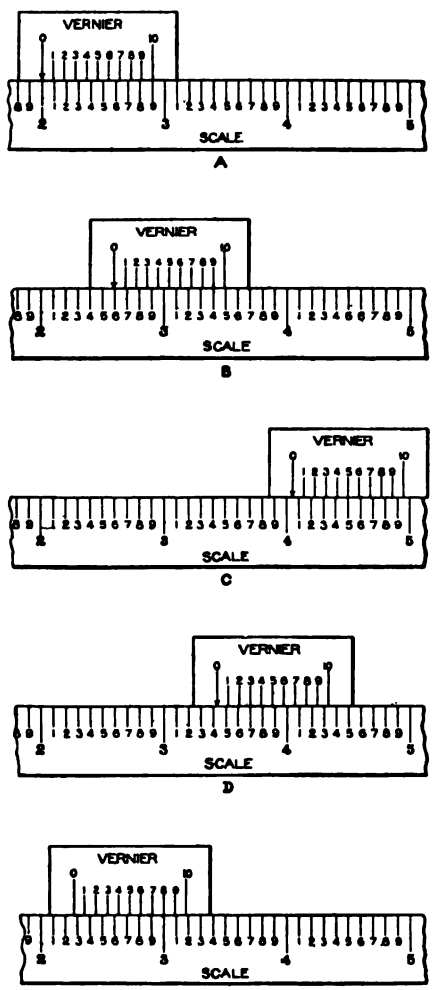


Fig. 26.

The Vernier. As has already been stated, the finest graduation that can be easily read on a steel rule by the naked eye, even after much practice, is one-hundredth of an inch. With the growing refinement in measurements, it was found necessary to obtain readings finer than this, and a method of subdivision, known from the name of the inventor, as the "Vernier," was adopted. The principle will first be explained. (See Fig. 26.)

Let two rules be so graduated that the true scale has each inch divided into ten equal parts, and the Vernier scale has ten divisions occupying the same space as nine of the divisions of the scale. It is evident that one of the divisions on the Vernier is equal to $\frac{9}{10}$ of one of those on the scale. Now, if the Vernier be moved to the right so that the graduations marked

1 shall coincide, the Vernier will have moved one tenth of a division on the scale, or one hundredth of an inch; when graduations numbered 5 coincide, the Vernier will have moved five hundredths of an inch; when lines marked 0 and 10 coincide, the Vernier will have moved nine hundredths of an inch; and when 10 on the Vernier comes opposite 10 on the scale, the Vernier will have moved ten hundredths of an inch, or the whole of one division on the scale. By this means the scale, although graduated only to tenths of an inch, may be accurately set at points whose positions are expressed in hundredths of an inch.

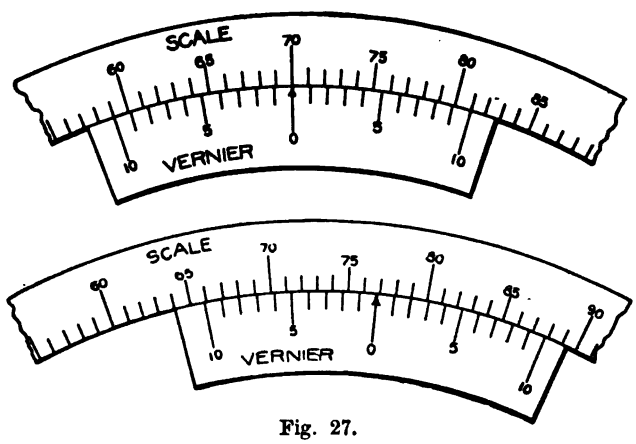


Fig. 27.

Let us consider Fig. 26. At A the Vernier is shown with the 0 in line with 2 on the scale; hence the reading is 2.000.

In B, the 0 of the Vernier has moved to the right beyond the division marked 5. The line 9 on the Vernier is in line with a line on the scale; hence the reading is 2.59.

In C, the zero of the Vernier has moved to the right still farther. The reading is evidently 4.05.

In D, the reading is 3.43.

In E, the reading is 2.28.

While arcs of small radius can be easily graduated into degrees, it is not possible to subdivide the degree without making the divisions confusing. By aid of the Vernier placed just above the true scale representing degrees, readings can be made with accuracy to one-tenth of a degree, or six minutes. The

divisions of such a Vernier scale are shown in Fig. 27, and are also shown when set to read 76° 48′.

The most common application of the Vernier to linear measurements is found in the Vernier caliper square. The one shown

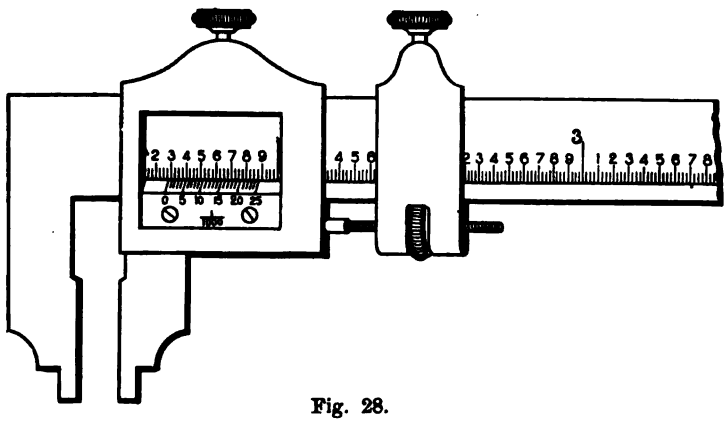


Fig. 28.

in Fig. 28 reads to one-thousandth of an inch. Each inch of the true scale, or beam of the instrument, is divided into 40 parts (every fourth graduation being emphasized), while the Vernier,

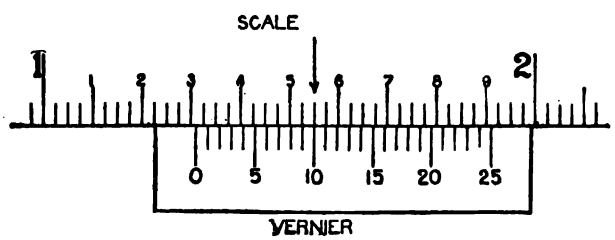


Fig. 28a.

or sliding-scale, has 25 divisions, occupying the same space as 24 divisions on the true scale. By the reasoning used in connection with Fig. 26 the difference in length of one division on the Vernier, as compared with one of those on the true scale, is equal to one twenty-fifth of one fortieth or one thousandth of an inch. The caliper square shown in Fig. 28 is set at .279 inch. The scale is also shown enlarged in which the reading is 1.31 inch.

By the use of the Vernier in connection with the micrometer caliper, readings are easily made to one ten-thousandth of an inch.

As shown in Fig. 29, lines are drawn on the barrel parallel to the reference line, making ten equal divisions occupying the same space as nine divisions on the thimble. Referring to Fig. 30, it will be seen that each division on the thimble may be accurately divided into ten parts, each indicating a difference in the position

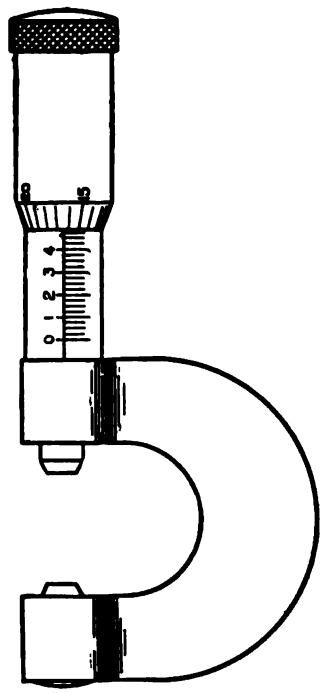


Fig. 25.

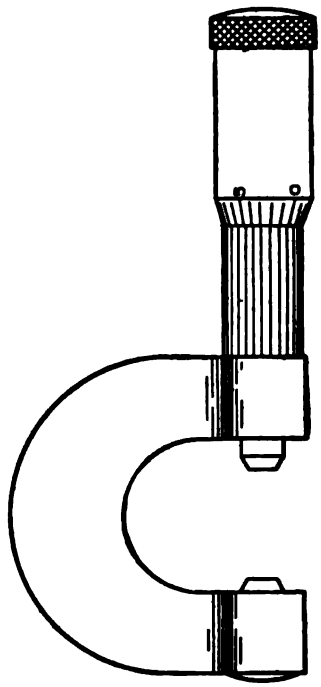


Fig. 29.

of the measuring point of one ten-thousandth of an inch. Rapid reading of the Vernier in any form can only be acquired by practice, but the following directions may be found helpful:

In Reading the Vernier, we must bear in mind the fact that each division on the Vernier is $\frac{9}{10}$ of one division on the scale, and that if line No. 1 on the Vernier is in line with any division of the scale the zero of the Vernier is $\frac{1}{10}$ of one division away from the graduation below it; if line No. 2 is in line, the zero is $\frac{2}{10}$ away from the graduation; if line No. 6 is in line, the zero is $\frac{6}{10}$ away.

Suppose the Vernier is in position on the scale and graduated

as shown in Fig. 30. First read the highest division on the scale to the left of the zero on the Vernier. (69 is the division in the figure.) Then follow along the scale (to the right) until two graduations are found that are in line, as at 6 on the Vernier and 75 on the scale. Now, since one division on the Vernier means that the zero is $\frac{1}{10}$ of a division of the scale away, six divisions of the Vernier means that the zero is $\frac{6}{10}$ away; hence the zero of the Vernier is $\frac{6}{10}$ beyond the 69, and the reading is 69 and $\frac{6}{10}$ or 69.6.

Arcs of circles, such as are on surveyor's instruments, may be graduated to read to half degrees if the diameter is about 8 inches. Now, if we put on the circle a Vernier graduated so that we have 30 divisions equal to 29 divisions of the scale (arc), we can read 30ths of half degrees or *minutes*.

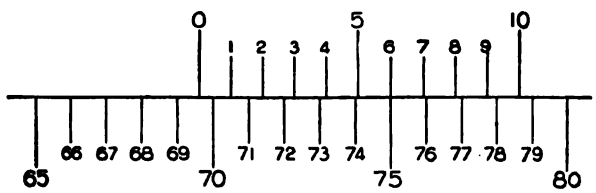


Fig. 30.

Vernier Micrometer. To get very accurate readings, a Vernier scale is placed on the barrel of the micrometer caliper. Let Fig. 29 represent the back side of the micrometer caliper shown in Fig. 25. The reading already obtained was .491 inch. Now turn the caliper over (Fig. 30), and, commencing at the right, count the graduations until one is reached that coincides or is in line with a graduation on the thimble. In doing this, call the first division zero, the second 1, the third 2, etc. The number of the division on the Vernier that is in line with the division on the thimble indicates the ten-thousandths above the regular micrometer reading. From Fig. 30 we see that the 5th line is the graduation which is in line with the division on the thimble which should be called 4, as explained above. Then the reading is .4914 instead of .4915, as we read it from the other side (the plain micrometer). With a good micrometer, we can be sure that the distance between the anvil and the point is more than .4913 and less than .4915.

The Retrograde Vernier. In addition to the direct Vernier, there is another form called the retrograde Vernier, which has 10 divisions on the Vernier and 11 on the scale. In this case the graduations on the Vernier must be reversed, as shown in Fig. 31.

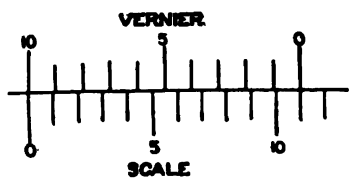
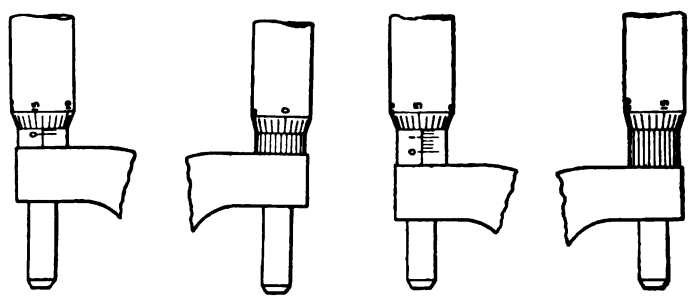


Fig. 31.

Calipers reading to ten-thousandths should not be commonly used when fine measurements are not required, because in an instrument of this class wear is perceptible and important which would be of comparatively little consequence in a caliper that reads only to thousandths.

In using the micrometer caliper for fine measurements, care should be taken in the handling of the instrument. Constant contact with the warmth of the hand will expand it sufficiently to make an error in the reading. The body should be held between the thumb and forefinger of one hand and the thimble turned with the other. It should be laid aside as soon as a reading has been made. It should never be laid upon a piece of cold iron, because the contraction due to chilling is likely to cause an error in the opposite direction from that which would be caused by the heat of the hand.



EXAMPLES FOR PRACTICE.

1. A micrometer caliper shows a reading of .463; how many times must the thimble be turned to produce a reading of .587? Assume 40 threads per inch. Ans. $4\frac{24}{40}$ times.

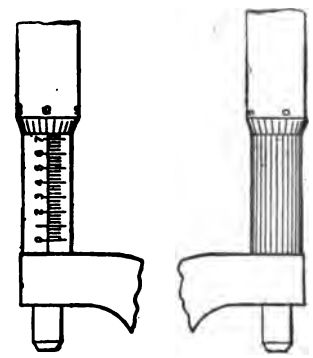
2. What are the readings of the Vernier micrometer calipers shown in Figs. A and B? Ans. A .031.

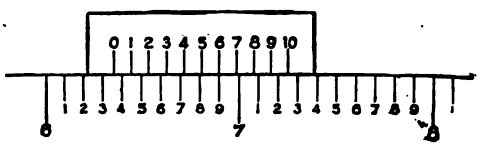
3. State the readings of the micrometer calipers shown in Figs. C and D. Ans. C .155.

4. Give the readings of the Vernier micrometer calipers shown in Figs. E and F. Ans. E .740.

5. Sketch the front and back of a Vernier micrometer caliper when the reading is .6327.

6. What is the reading of the Vernier and scale when in position G? Ans. G 6.36.





Fixed Gauges. While the adjustable gauges that have just been described are available for a large range of work, gauges of one dimension, or fixed gauges, are used to a considerable extent, especially in shops where work of a duplicate character is produced in large quantities. These may be used as standards to which adjustable gauges may be set, or used directly in connection with the work in the same manner as an adjustable gauge. The form of such gauges for comparisons of length is a steel rod with the ends carefully ground so that the distance required may be quickly and accurately determined. In one form the ends are parallel plane surfaces, and in another the ends are sections of a sphere of the same diameter as the length of the rod. Both these forms are illustrated in Fig. 32. Another form of gauge for the same purpose consists of hardened and ground steel disks, Fig. 33, to which calipers and similar tools may be set, and which may be used also to test the size of holes by direct application. For the latter purpose handles are provided by which the disks can be conveniently manipulated.

Plug and ring gauges, as shown in Fig. 34, furnish accurate and convenient standards for the production of duplicate parts of machines. The same result is attained by the caliper gauge shown

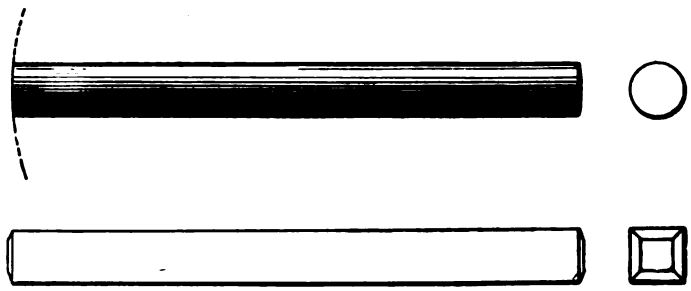


Fig. 32.

in Fig. 35, which combines the two gauges in one piece. In this form the external gauge has parallel plane surfaces and the internal gauge is a section of a cylinder. In sizes above three

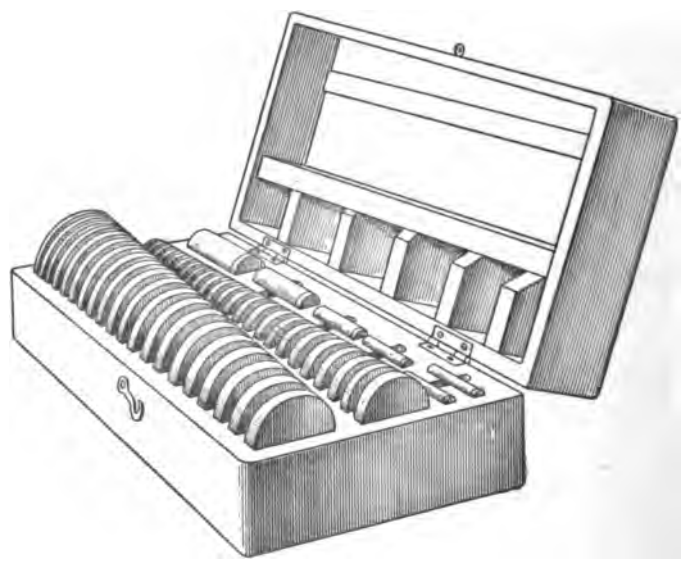


Fig. 33

inches, the caliper gauge is usually made in two parts, also shown in Fig. 35, making the tool easier to handle.

As is indicated by the cost of these gauges, the exact duplication of such exact sizes in quantities would mean a cost that

would be prohibitive in machine construction. The limit of error in the standard gauges just described is never over one ten-thousandth of an inch at a standard temperature, which is usually taken as 70° F. Ordinary machine parts do not require such accuracy,

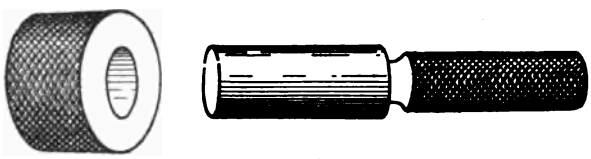


Fig. 34.

and it is usual to allow a limit of error which is in accordance with the class of work being produced.

For testing sizes and dimensions, both at the machine and in the inspection department, combination gauges, known as **limit gauges,** are employed. These are made both for external and

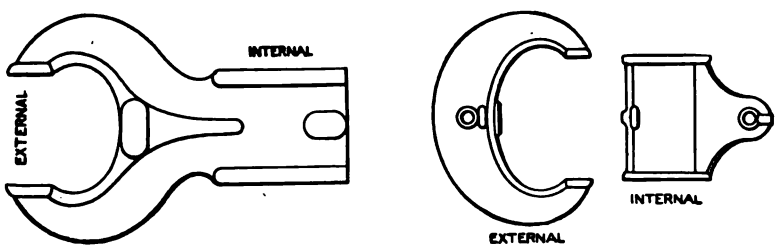


Fig. 35.

internal measurements. The external gauge shown in Fig. 36 is for testing pieces supposed to be .25 inch in diameter. As indicated by the figures on the gauge, the piece is allowed a variation of .0005 inch over, and .001 inch under the nominal size. The words "go on," and "not go on," stamped near the ends, indicate clearly how the gauge is used. This gauge is more conveniently arranged as shown in Fig. 37, in which the work must enter the first parallel opening, but must not pass through the second. In this form, one motion tests the piece for variation above and below the standard. Fig. 38 shows a limit gauge for holes, the end marked "go in" being required to pass into the hole, while the

other end, marked "not go in," must not enter. An arrangement of the internal limit gauge similar to the external gauge of Fig. 37 is shown in Fig. 39, and has the same advantages.

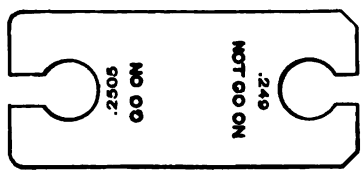


Fig. 36.

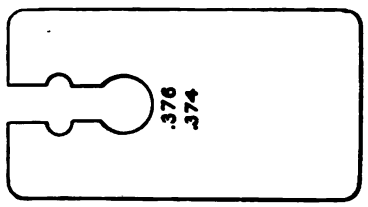


Fig. 37.

In some classes of work, no variation is allowed over the standard, and in others, no variation is allowed under the nominal size. The amount of variation allowed in any case is governed by the class of work and the intended use of the piece. As

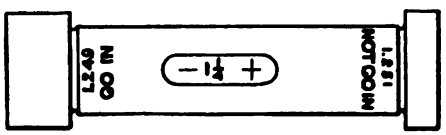


Fig. 38.

these allowances are not uniform, such gauges are made only to order.

For many years gauges of an entirely different character have been used in the measurement of wire, small rods, and sheet metal. The sizes have been designated, not by the diameter or any definite unit, but by a number or letter in a purely arbitrary manner. Even in the same gauge, the sizes do not advance in any regular order. The matter is still further complicated by the fact that in one gauge large numbers indicate large sizes, while in another, the smaller numbers mark the large diameters. Another source of annoyance lies in the fact that such gauges are cheaply made and cannot be relied upon to be duplicates of one another. These gauges were the natural result of the recognition of large manufacturers of the necessity of standards by which to grade their products. Hence we have such gauges as the Brown and Sharpe, Birmingham or Stubs, Washburn and Moen,

United States standard, Morse Twist Drill Co., and many others. As a step in the right direction, a decimal gauge has recently been adopted, in which the sizes are indicated by numbers which represent the diameters in thousandths of an inch. Most of these

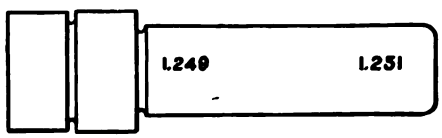


Fig. 39.

gauges had their origin in days when refined measurements were not common, but since the use of the micrometer caliper has become almost universal, there seems to be no good reason why all sizes should not be expressed in thousandths of an inch, thus

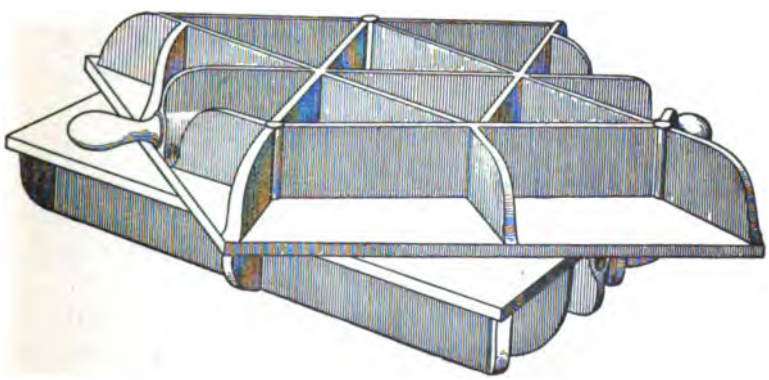


Fig. 40.

avoiding all the troubles incident to the use of the arbitrary gauges.

For the production of accurate plane surfaces the use of the straight edge is not sufficient. Such surfaces should be compared with standard surfaces called surface plates, Fig. 40. A surface plate is a cast-iron plate strongly ribbed on the back to prevent distortion, and supported on three points to insure a uniform base. The production and use will be described under the head of " Scraping." They may be had in sizes varying from 3 inches by 4 inches to 36 inches by 72 inches.

The machinist's **bench** at which hand work is ordinarily performed should be of substantial character, about two feet ten inches from the floor and two feet six inches wide (see Fig. 41). For the sake of economy it is usual to have a two and one-half or three inch plank at the front to which the vises are fastened and on which all the heavy work is done, while the rear of the bench is made from one-inch stuff. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

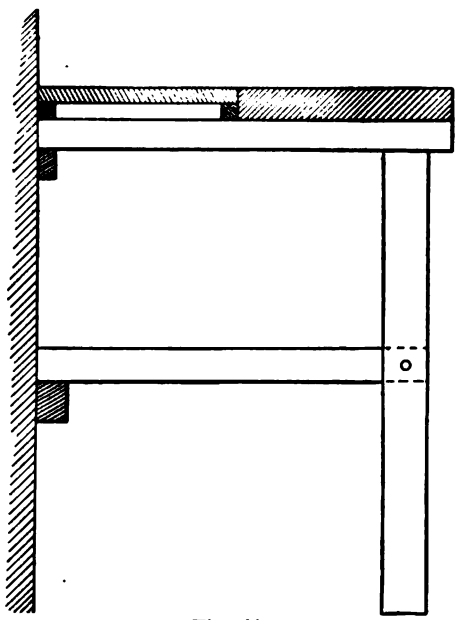


Fig. 41.

In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a *vise*. They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 42, shows these parts clearly and also a device, present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out in the nut.

In the machinist's vise, both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid the marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 42, although a swivel base such as is shown in Fig. 43 is preferable. The vise shown in Fig. 43 has a swivel jaw also which enables it to hold tapered work securely. This swivel jaw is provided with a locking-pin which fixes the jaws in a parallel position. The height of the

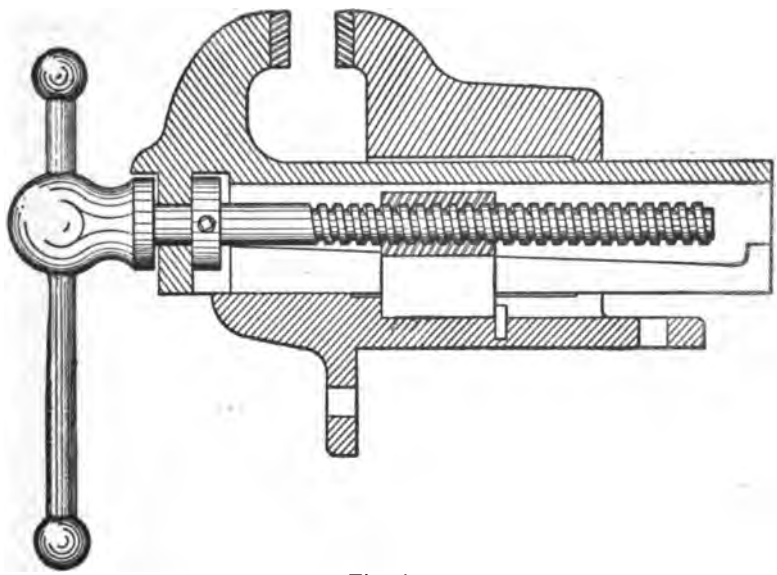


Fig. 42.

vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaws about one and one-half inches below the point of the elbow when standing erect beside the vise.

CUTTING TOOLS.

The simplest form of metal-cutting tool is the chisel. The several types in common use are shown in Fig. 44. The **flat chisel** is used for snagging castings, for chipping surfaces having less width than the edge of the chisel, and for all general chipping operations. It is the form most commonly used, and is often called the cold chisel. Generally it has a cutting edge

about an eighth of an inch wider than the stock from which it is forged. The **cape chisel** is used for cutting key ways, channels, etc., and also for breaking up surfaces too wide to chip with the flat chisel alone. Channels are driven across such a surface, leaving raised portions or "lands" to be removed by the flat chisel. The cutting edge of this chisel is usually one-eighth of an inch narrower than the shank, and the part just in the rear of the cutting edge is made thin enough to avoid binding in the

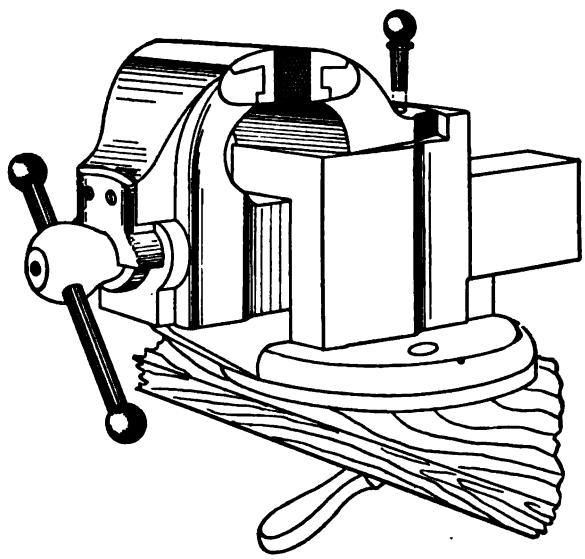


Fig. 43.

slot. As this weakens the chisel, it is made comparatively thick in the plane at right angles to the cutting edge.

The **diamond point** chisel is made by drawing out the end of the stock to about $\frac{5}{16}$ inch square, and grinding the end at an angle with the axis of the chisel, leaving a diamond-shaped point. It is used for drawing holes, making oil grooves, and cutting holes in flat plates.

The **small round-nosed** chisel is cylindrical in section near the cutting end, the edge being ground at an angle of 60° with the axis of the chisel. When used to "draw" the starting of drilled holes to bring them concentric with the drilling circles they are called **center chisels.** This form is also used fo

cutting channels such as oil grooves and similar work. The larger sizes of round-nosed chisels are of the general shape of the cape chisel with one edge rounded, making a convex cutting edge. Large round bottomed channels and all concave surfaces are the proper work of the round-nosed chisel.

All the accompanying forms should be made from a good grade of tool steel, carefully forged, hardened, and tempered to a purple color. The stock generally used is octagonal, and the chisels for heavy work are about eight inches long and three-quarters of an inch in diameter.

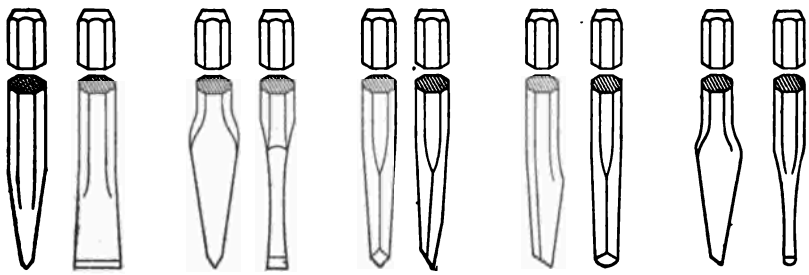


Fig. 44.

The two bevels forming the cutting edge of a chisel should make with each other as small an angle as is possible without leaving the cutting edge weak. If the angle is too small, the chisel will soon become dull, while if large, more force will be required to drive it. The best angle for cutting cast iron, all things considered, is about 70°, while for wrought iron and mild steel a slightly smaller angle, say 60°, will be better. When there are two bevels, they should be alike in width, and form equal angles with the center line of the chisel. Small round-nosed chisels and some slotting chisels are ground one-sided, that is, with but one bevel like a wood chisel. The angle between the surfaces which form the cutting edge should be the same, whether these surfaces are both bevels, or one a bevel and the other the straight side of the chisel. In a one-sided chisel, therefore, the angle that the bevel forms with the center line of the chisel should be twice as large as in one having two bevels.

To cut well, chisels should be sharp, and therefore should

be ground at once when they become dull. This may be done on an emery or carborundum wheel, not finer than No. 60, care being taken to avoid heating, which draws the temper, and spoils the tool.

Chipping is a term applied to the removal of metal with the cold chisel and hammer. The degree of accuracy required varies. The piece is held in a vise, and the method of working is to grasp the chisel firmly with the left hand, holding the cutting edge to the work, and striking the head of the chisel with the hammer, keeping the eyes on the edge of the chisel to watch the progress of the work (see Fig. 45). The lower side or bevel of the chisel is the guiding surface, and is held at a very slight angle with the finished portion of the work, the cutting edge only touching. Raising or lowering the shank of the chisel increases or decreases the inclination of the guiding bevel, and causes the chisel to take a heavier or lighter cut. If the hand is carried too low, the chisel will run out before the end of the cut; while if the hand is raised too high, the progress will be slow, owing to the resistance offered by the metal to separation. The depth of the cut taken with a cold chisel should never be more than an eighth of an inch.

Fig. 45.

When chipping wrought iron or steel, a piece of waste saturated with oil should be kept on the bench, and the edge of the chisel frequently thrust into it. This lubricates the surfaces in contact and preserves the cutting edge of the chisel. While lines are used as guides in chipping operations, it is never advisable to bring the surfaces too near them with the chisel; sufficient stock must be left so that the surfaces may be finished with a file. This

is especially to be observed in chipping key ways with a cape chisel; an ample margin for filing should be left, both on the sides and on the bottom.

The file differs from the chisel in having a large number of cutting points instead of one cutting edge, and in being driven

Fig. 46.

directly by the hand instead of by the hammer. As hand power only is used, it is evident that the amount of metal removed at one stroke will be small, and the amount removed by a single tooth will be exceedingly small.

Files are made from cast or crucible steel, and in manufacture pass through the successive processes of forging, annealing, grinding, cutting, hardening, and tempering. They have three distinguishing features, viz., length, kind or name, and cut or

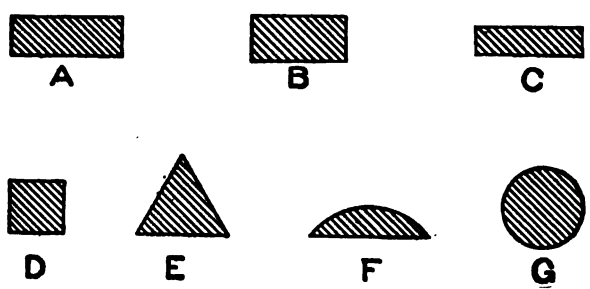


Fig. 47.

coarseness of teeth. Length is measured from the heel A to the point B, Fig. 46; the tang C not being included. These lengths vary from three inches to twenty inches.

There are many kinds manufactured, those in common use being the flat (*a*), hand (*b*), warding (*c*), square (*d*), three square or triangular (*e*), half round (*f*) and round (*g*), sections of which are shown in Fig. 47.

The cut of files is in two styles, single and double; and each style has several grades of coarseness, viz., coarse, bastard, second-

cut, smooth, and dead smooth. The last two grades are sometimes called fine and superfine. As is shown in Fig. 48, the coarseness of each style varies with the length — the longer the file the coarser the cut.

If the cutting surface of a file were perfectly flat, the number of teeth or cutting points engaged with the work would depend on the width of the file and the width of the piece being filed. To force as many cutting points as would be contained in such a large area deeply enough into the metal to enable each to remove its share of the stock, would be beyond the power of the man pushing the file. To avoid this necessity for great pressure, files are usually "bellied" or made slightly convex in the direction of their length, so that, theoretically, the file and the work are in contact only on a line as long as the width of the file. This enables the file to be forced into the metal sufficiently for the teeth to bite, and thus avoids dulling the teeth, which always occurs when the file is allowed to glide over the work without sufficient cutting.

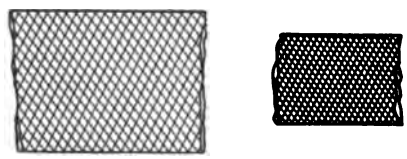


Fig. 48.

This convexity of files also serves another purpose. The pressure applied to the file to make it bite bends the file more or less (see Fig. 49), and if the file in its natural state were perfectly flat, when cutting it would be concave; and this would prevent the production of a flat surface. It would cut away at the edges of the work and leave a convex surface. Such files might, however, be used on convex surfaces.

Work for filing is usually held in a vise such as has already been described, and under ordinary circumstances the surface of the work should be about the height of the elbow. For fine work with small files, where close observation is of more importance than pressure on the file, the work should be higher than this, the height increasing with the refinement of the work. On the other hand, for very heavy filing, where great pressure is absolutely necessary, the work should be several inches below the point of the elbow, so that the weight of the body may be used to good

advantage, and also because the workman naturally stoops a little when exerting great pressure on the file.

The handles commonly attached to files are made of wood and are made to fit the hollow of the hand. They are driven onto the tang of the file; a ferrule on the handle preventing it from splitting. Care should be taken to have the axis of the handle parallel with the file. A good way to prepare the handle for the tang is to heat the tang to a dull red, the file proper being kept cool by a piece of wet waste, and the hole in the handle burned

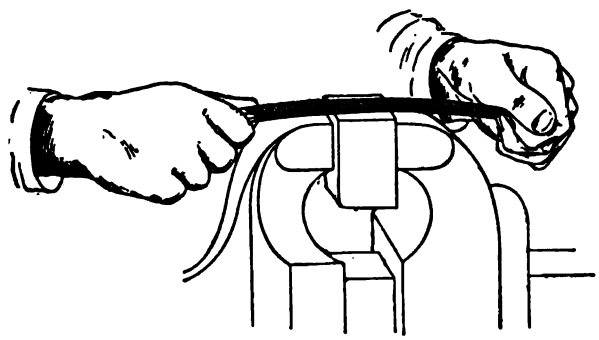


Fig. 49.

out until the tang is almost in the position it is designed to finally occupy. After cooling the tang, very little driving will be required to securely fasten the handle to the file.

When filing surfaces of such size that the handle as ordinarily applied would interfere with the use of the file, the tang may be bent up to an angle so that the handle will clear the surface. Various forms of holders are used for filing under these circumstances; the simplest forms being shown in Fig. 50.

The correct position for filing is about as follows: feet about eight inches apart and at right angles, the left foot being in line with the file; stand back from the vise so that the body may follow the file slightly; grasp the file handle with the right hand, fingers below, thumb on top of the handle; for coarse filing, place the ball of the thumb of the left hand on the point of the file; for fine filing grasp the point of the file with the thumb and forefinger of the left hand. See Fig. 51. When holding the file in one hand, as is often done in light work, the forefinger should be

on top of the file pointing in the direction of its length, as is shown in Fig. 52. This allows free movement of the hand and wrist, pressure being applied principally by the forefinger.

As file teeth or cutting edges point toward the end of the file, it is evident that the file can cut only when moving in a forward direction. On the return stroke, the pressure should be relieved; otherwise the teeth will be dulled when drawn back over the surface.

The kind of metal being worked determines in a great measure the character of the file to be used. Cast iron, especially if the scale has not been previously removed, is particularly hard on a new file, as the glassy character of the scale tends to dull the cutting edges. New files should never be used on such a surface. It is found that on tool steel, and hard materials generally, a sec-

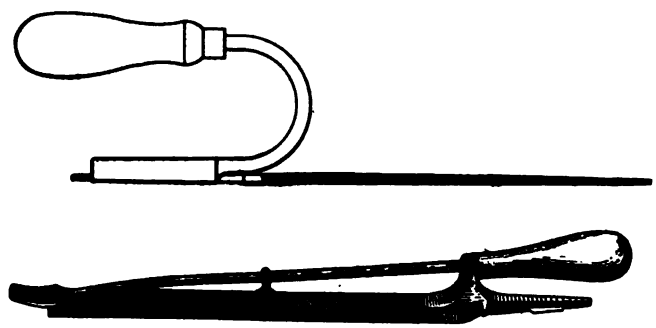


Fig. 50.

ond-cut file is better than the bastard. This is because if pressure enough is exerted to cause the coarse teeth of the bastard to bite into the work, the teeth, being comparatively long, are very likely to be broken off. In the second-cut file, the teeth are shorter and present more cutting points in a given area; thus preventing excessive duty being imposed on a few teeth.

Softer metals, such as brass and bronze, allow the use of the coarser grades.

The particles of metal removed by a file frequently remain in the teeth and diminish their cutting qualities. In the case of hard metals these particles, or "pins," often scratch the work. It is necessary, therefore, that files be frequently cleaned. This may

be done in a measure by striking the edge of the file lightly against the bench or vise, but it is more effectually performed by using a stiff brush or a piece of card clothing (Fig. 53). In the finest grades of files, a thin piece of wood or sheet brass may be drawn across the surface of the file as shown in Fig. 54, and the filings are removed by the points extending into the file teeth.

When filing cast iron, neither the file nor the work should be allowed to become greasy, as this tends to make the file slide without cutting. In filing steel, however, if the file be oiled or filled with chalk, the pinning of the file is prevented in a large degree, and frequent use of the card or brush is not necessary.

Fig. 51.

What is known as drawfiling is done by grasping the file at each end and moving it sidewise across the work. (See Fig. 55.) The amount of stock removed by this process is usually very small, the object being to lay the file-marks parallel to the length of the work. Single-cut files are better than double-cut for this purpose, being less likely to scratch the work. The remarks concerning cleaning, oiling, and chalking apply both to cross-filing and draw-filing.

No matter how carefully filing is done, it does not leave a

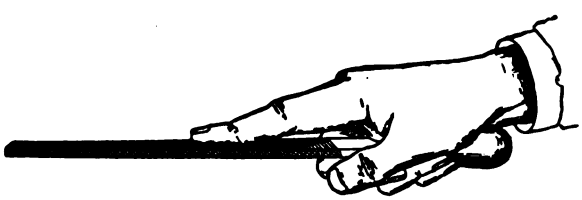


Fig. 52.

surface that is pleasing to the eye; the file-marks are more or less irregular and the whole surface is dull. Exposed parts of machines which are not painted are usually polished. Polishing

does not improve the surface, but simply brightens it and renders it more attractive. As a rule, a polished surface is not a true surface, no care being taken to maintain its truth. In ordinary machine work polishing is usually done by abrasives, such as emery, corundum, and carborundum, while rouge, crocus, rotten-stone, and tripoli are used on fine work, especially on brass and

Fig. 53.

composition. Emery, for example, is crushed and sorted into grades varying from No. 8 to flour, the number of the grade indicating the number of meshes per inch in the sieve used in sorting. These grades sometimes bear arbitrary designations, No. 1 indicating a coarse grade and No. 0, 00, 000, 0000 showing the finer grades. These powders are sometimes mixed with oil and applied directly to the work by wooden blocks or clamps; but

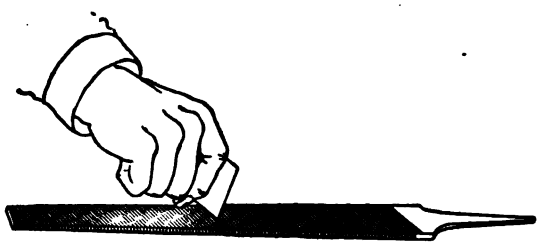


Fig. 54.

the more common method is to use what is known as emery cloth, the grains being glued to a strong cloth backing. The finer grades are used on paper in the same manner.

Emery cloth is used in many ways; it may be wrapped around a file; folded or tacked to a block of wood; glued to wooden sticks about 15 inches x 1½ inches x ½ inch, fastened around rollers for internal curves, or glued to wooden or steel disks and rotated in a lathe or special machine. In all cases the object is to grind down the surface, using a sufficient number of grades of cloth to produce the degree of polish desired. The

marks are laid parallel to each other, making what is known as a "grain." When the process is to be carried to such an extent that no grain is to be visible, the finer polishing agents are used,

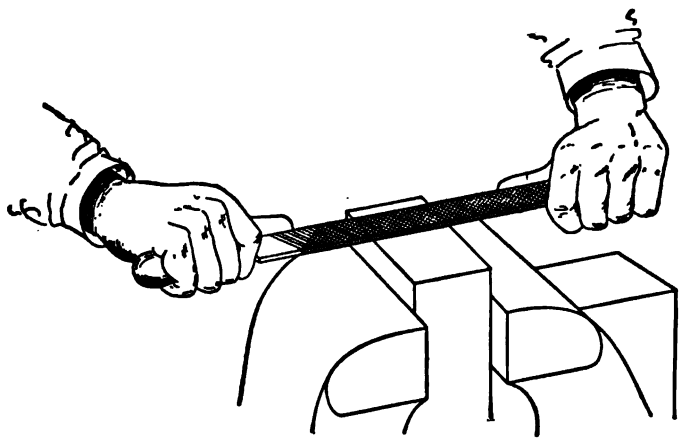


Fig. 55.

usually applied with a cloth wheel or "lap." Old cloth does finer work than new, and oil on the cloth will make a finer cut.

Scraping. When two flat or curved surfaces are to be worked together, and complete contact over the whole or both is desired, they are scraped. Scraping removes less metal than filing, and also enables the workman to confine the removal to limited areas. The scraper should be made from a very close-grained tool steel, and is nearly two feet long exclusive of the

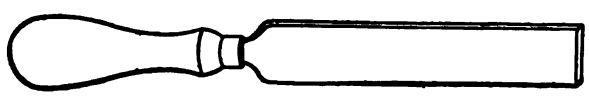


Fig. 56.

handle. The general shape is shown in Fig. 56. The cutting edge is about $\frac{3}{32}$ of an inch thick and $1\frac{1}{2}$ inches wide. It is ground on an emery wheel and grindstone, and carefully oilstoned, leaving the cutting edge as straight as possible. Scrapers are sometimes made from old files, the teeth being ground off and the end drawn out wide and thin. Sometimes the end is bent at right angles to the shank, as shown in Fig. 57. The cutting done by scrapers should be perfectly smooth and free from scratches.

In using the surface plate as a test for the truth of a plane, such as a valve or its seat, the plate is covered with a very thin coating of red lead and then rubbed over the valve or seat. The latter should have previously been finished as smoothly as possible. The spots where the red lead shows contact are scraped off, and

Fig. 57.

the process continued until contact over the entire surface is obtained. During the last part of the operation alcohol should be used instead of red lead, as it leaves clean bright spots to indicate where the scraper must be applied. Small pieces of work are rubbed over the surface plate, and in any case care should be taken to distribute the wear uniformly over the plate in order to prolong the truth of the plane. The scraper for concave surfaces, such as boxes, is of the general shape of a half-round file without teeth. In such cases, the shaft to be used takes the place of a surface plate. The method of holding and using such a scraper is shown in Fig. 58.

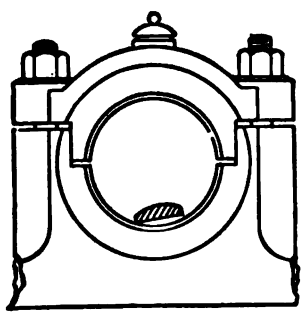


Fig. 58.

Scraping is sometimes done as a matter of finish, and not for the purpose of getting an accurate surface. Therefore, a scraped surface does not always indicate accuracy. Many machine parts are more cheaply finished by scraping than by polishing.

DRILLS.

Drills are of two general classes, the flat and the twist. A flat drill of a common type is shown in Fig. 59. The angle between the two cutting edges should be about 110°. These drills

are usually made from round tool steel drawn out wide and thin, as shown; the undressed end being used for holding. The flat drill is usually made in the shop where it is to be used. Its low first cost is the principal reason for its existence.

Flat drills made from thin flat stock are used in connection with a slotted rest to start and drill holes in the lathe without

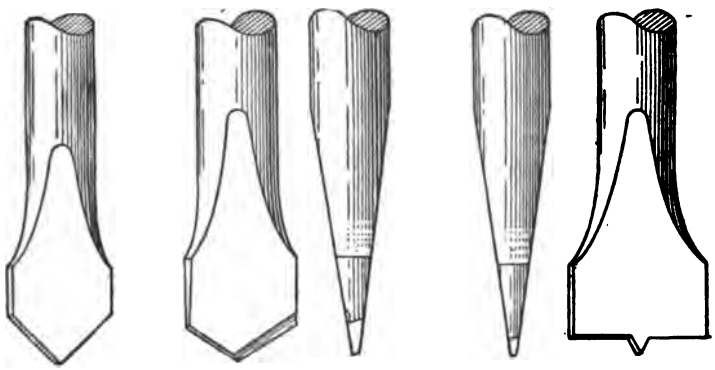


Fig. 59.

previous centering. They are called **chuck-drills.** The end of the shank of the drill is provided with a center hole to receive the dead center of the machine. The drill and rest are shown in Fig. 60.

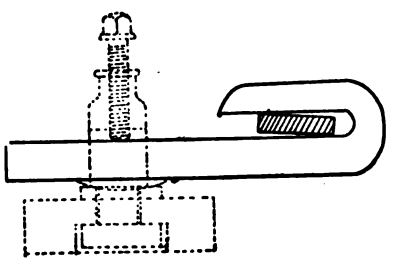


Fig. 60.

The simplest form of **twist drill** is cylindrical throughout its entire length, as shown in Fig. 61, and has two opposite spiral flutes which at the end serve to form the cutting lips, and which also serve to carry the chips from the hole. The included angle of the lips is 118°. This form of drill will work more accurately than the flat drill, as the cylindrical portion serves as a guide to keep the cutting lips in their proper position. The edge being somewhat hooking, removes the metal by a cutting instead

of a scraping action as in the flat drill. This form of drill cannot only be fed faster, but can be forced into the work with less power, as it has a tendency, especially noticeable in soft metals, to feed itself into the work. Straight shank twist drills are made from

Fig. 61.

.0135 inch to 2½ inches in diameter; the smaller sizes are sold in sets designated by numbers (1 to 80), letters (A to Z) or fractional sizes ($\frac{1}{2}$ inch to $\frac{1}{16}$ inch).

The *taper-shank twist drill* is shown in Fig. 62. It consists of a body A, which is fluted and does the actual work, and a taper shank B, by which it is held. This taper fits accurately into the spindle or chuck of the drill press. At the end there is a tongue C, which slips into the key way in the spindle or chuck. As this

Fig. 62.

surface is flat, it serves as a bearing by which the drill is driven. This relieves the tapered portion from the stress of driving by frictional resistance alone. For small drills this frictional resistance is sufficient, but for larger sizes it will not do at all. If for any reason the tongue should become broken, no dependence should be placed upon the frictional resistance of the taper shank to drive the drill. The drill will slip and wear the socket, which will become enlarged and make a misfit for other drills.

The **standard taper** for drill shanks may be considered to be what is known as the Morse. This taper is $\frac{5}{8}$ inch to the foot. There is another known as the Brown & Sharpe or Jarus which has a taper of $\frac{6}{10}$ inch to the foot. No attempt should be made to run the drills of one taper in the sockets of the other.

A flat taper key, introduced into the key way, engages the end of the tongue and serves to remove the drill from the spindle.

Drills of cylindrical form are also made with straight flutes as shown in Fig. 63. They are used for drilling soft metals, such as brass, especially when the drill passes entirely through the piece. As it breaks through the metal, a drill with spiral flutes tends to draw itself through rapidly, as if it were a screw work-

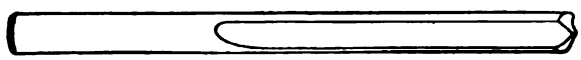


Fig. 63.

ing in a nut. This may break the drill or move the work from position. Straight flutes give the same cutting action as a flat drill and avoid this tendency to draw.

Lubrication of Drills. When drilling tough metals such as steel, wrought and malleable iron, heat is generated by the bending or changing of the form of the metal being removed and by friction caused by the chips moving over the lips of the drill. The heating is similar to the heating of a piece of wire bent quickly back and forth. As there is danger of heating the drill to a temperature that will draw the temper and soften the drill, plenty of lard

Fig. 64.

oil, or a mixture of potash and water, should be used. This is not so much for lubrication as to remove the heat.

Copper is the most difficult to drill of all the common metals on account of its extreme toughness; then, too, copper heats to a higher temperature on account of its low specific heat. Brass does not require the use of oil, and cast iron must always be drilled dry. Particular attention is called to this precaution regarding cast iron.

As the heat is produced at the point of the drill, it is desirable, particularly in the case of deep holes, that the oil be applied directly at the drill point. For this purpose, oil-tube drills, such as is shown in Fig. 64, are used.

The oil is supplied under pressure, and not only removes the heat, but also carries away the chips.

Speed of Drills. The speed at which drills should be rotated depends on the diameter of the drill and the material operated upon. No absolute rule can be given for any one metal or diam-

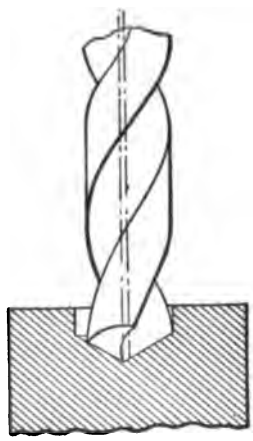


Fig. 65.

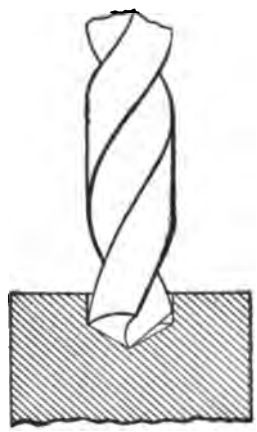


Fig. 66.

eter of drill, because of the variation in hardness and tenacity of the material and the condition of the cutting edge of the drill.

The following table of revolutions per minute, given by the Cleveland Twist Drill Co., is based on a peripheral speed of 30 feet a minute for mild steel, 35 feet per minute for iron, and 60 feet per minute for brass.

The rate of feed also depends on the drill diameter and the material. The above mentioned authority gives, as a maximum, one inch of feed for 95 to 125 revolutions.

Grinding Drills. Great care should be exercised in the grinding of drills. The end of a drill should be symmetrical; that is, the lips should be of the same length, and form the same angle with the axis. If the lips are of unequal length, the hole will be larger than the drill, as is shown in Fig. 65. The point is not in the axis, and the hole will not only be large but also will not be parallel to the drill spindle. If the lips do not form equal angles with the axis, all the cutting will devolve upon the one making the greater angle as shown in Fig. 66. Such a drill will not cut as fast as, and will become dull sooner than, one which is properly ground.

Hand-grinding, especially of twist drills, is neither accurate nor satisfactory; it is much better to do such work on a regular drill grinder built especially for the purpose.

SPEED OF DRILLS.

Diameter of Drill.	Speed for Soft Steel or Wrought Iron.	Speed for Cast Iron.	Speed for Brass.
1/16	1824	2128	3648
1/8	912	1064	1824
3/16	608	710	1216
1/4	456	532	912
5/16	365	425	730
3/8	304	355	608
7/16	260	304	520
1/2	228	266	456
9/16	203	236	405
5/8	182	213	365
11/16	166	194	332
3/4	152	177	304
13/16	140	164	280
7/8	130	152	260
15/16	122	142	243
1	114	133	228
1 1/16	108	125	215
1 1/8	102	118	203
1 3/16	96	112	192
1 1/4	91	106	182
1 5/16	87	101	174
1 3/8	83	97	165
1 7/16	80	93	159
1 1/2	76	89	152
1 9/16	73	85	145
1 5/8	70	82	140
1 11/16	68	79	135
1 3/4	65	76	130
1 13/16	63	73	125
1 7/8	60	71	122
1 15/16	59	69	118
2	57	67	114

While grinding, care must always be exercised that the cutting edge is not overheated on the stone or emery wheel. If it is overheated, the temper will be drawn and the drill become too

soft to properly do its work. The angle between the front face of the drill and the bottom of the lip may be from 70 to 80 degrees. This will give ample clearance for the bottom of the drill and leave sufficient metal to support the cutting edge.

REAMERS.

It is difficult, if not quite impossible, to drill a hole to an exact nominal diameter. For most work, a variation of a few

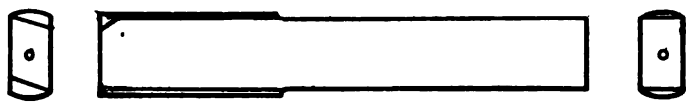


Fig. 67.

hundredths of an inch from the nominal diameter is of no account. Where greater accuracy is required the holes are reamed; that is to say, the hole is first drilled somewhat smaller than it is desired, and is then reamed out to the proper size with a reamer.

Holes drilled with the flat chuck drill mentioned above are usually $\frac{1}{16}$ inch under the finish size. A flat chuck reamer, Fig. 67, is used to enlarge the hole to within about .005 inch of the true size. This reamer is centered on both ends and turned to size.

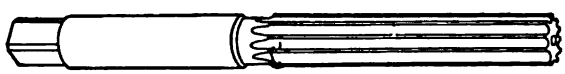


Fig. 68.

The entering rod, which does the cutting, is given a short, sharp taper, while the straight portion serves as a guide to keep the tool in position. By this means the drilled hole is straightened and brought close to size.

To give the hole a smooth surface and correct diameter, a fluted reamer (of which there are various forms) is used. This tool is not intended to remove large amounts of metal, but serves

only to increase the size of a hole by a small fraction of an inch up to the diameter required. The hole should not be more than $\frac{1}{64}$ inch smaller than the reamer; this will leave $\frac{1}{128}$ inch on each side for the reamer to cut. If possible, it will be better to drill the hole even nearer than this to the required diameter.

It is evident that if the reamer were to be made of the same diameter throughout its whole length, it would be very difficult

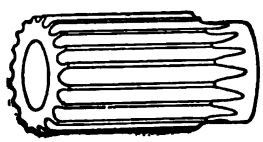


Fig. 69.

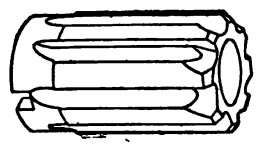


Fig. 70.

to make it enter the hole. In order to facilitate this, it is usually made slightly tapering, for a distance from the entering end, equal to about one diameter.

One form of reamer has a shallow screw thread cut at the entering end. This thread takes hold of the metal and draws down into the work. When using a reamer, it is always well to pass the entire tool through the hole. The leading end is sub-

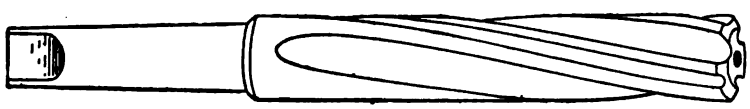


Fig. 71.

jected to the greatest amount of wear because it does the greatest amount of work. If, therefore, only the leading end is put through, the hole will not be of a uniform diameter throughout. Oil should always be used on reamers when they are working in wrought iron or steel.

The hand reamer, Fig. 68, is the typical form, and one which can be used in many cases in place of special forms. Fig. 69 is better adapted than the hand. This may follow the flat chuck reamer to finally finish a hole.

In reaming cored holes, the cylindrical chuck reamer, sometimes called the roughing reamer, is often used. It is made either rose, Fig. 70, fluted, or with three spiral flutes, Fig. 71, and generally have solid shanks. The last-named style will finish very smooth and close to size when started true by preliminary boring.

A solid reamer cannot be sharpened without reducing its diameter; therefore, it must be used carefully in order to prolong

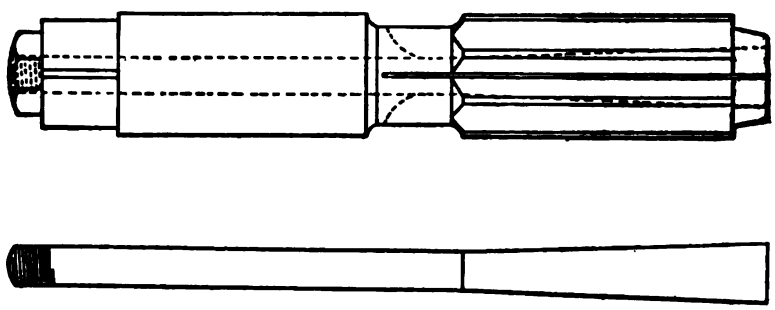


Fig. 72.

its life. Reamers with adjustable blades meet this objection, but cost much more than the solid form. An expanding reamer, Fig. 72, can be slightly enlarged to compensate for grinding, and is then used as a solid reamer. Fig. 73 shows an adjustable reamer with inserted teeth.

Reamers are made for tapered as well as for straight holes. The angle varies with the intended use of the taper; for example,

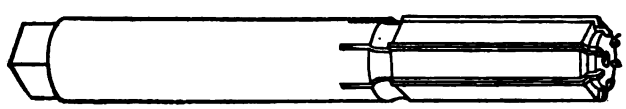


Fig. 73.

the *locomotive taper* of $\frac{1}{16}$ inch per foot is intended for bolt holes where plates are to be drawn solidly together and the holes completely filled. It is very difficult to remove a bolt from a hole with such a slight taper. When pieces are pinned together, such

as a hub to a shaft, it is intended that they can be separated when desired, so the taper is made steeper, generally ¼ inch per foot. This has come to be known as the *pin taper*. Taper holes for holding lathe centers and taper shank twist drills are generally made ⅝ inch

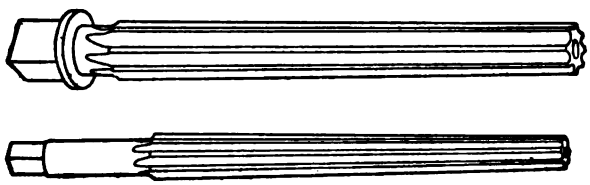


Fig. 74.

per foot (*the Morse taper*). This angle holds the tool firmly, and still it can be easily removed. The three tapers mentioned are recognized as standard, and reamers for them are carried in stock. Of course many other tapers are used by different manufacturers, but they are regarded as special. Fig 74 shows taper reamers.

Taper reamers differ from hand reamers only in the angle and by not requiring the tapered entering end.

Holes to be reamed by taper reamers must be slightly larger than the small end of the reamer; and, if the hole is deep, it is usual to make a stepped hole, shown exaggerated in Fig. 75, by using drills of different diameters.

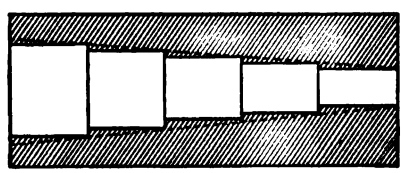


Fig. 75.

When not carefully sharpened, all forms of reamers have a tendency to chatter and produce rough surfaces. To avoid this, the flutes are frequently irregularly spaced; another method is to use spiral flutes, usually left hand.

TAPS.

When internal thread cutting is done, the tool is called a tap. There are many styles of taps; the names in some cases are sug-

gested from the shape, but more often from the use. In most machine shops are found the following forms: hand, machine screw, pipe, pulley, stay-bolt, boiler, and tapper; of these the hand and machine screw are the most common. The object of all is to make spiral grooves, called threads, in holes, so that they may receive and hold screws, bolts, studs, etc.

As the size of a tap is the diameter outside the threads, it is evident that the hole drilled for tapping must be smaller than the

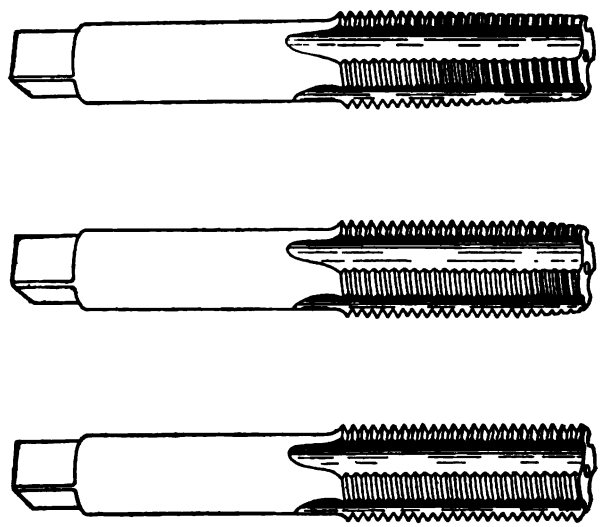


Fig. 76.

tap by nearly, if not quite, twice the depth of the thread. The shape of the thread partly determines the amount to be subtracted from a tap diameter. There are now recognized as standard, five different threads, viz.: sharp or V, Franklin Institute or United States standard, Whitworth, International or metric, and the 29° or Acme. These shapes will be described and compared under Screw Cutting. The following table shows the diameters of the holes that are to be drilled for cutting the various sizes of the threads according to the United States standard and the ordinary V-thread.

Hand taps are most commonly used in shop practice, and a description of the operation will answer for all styles. They are usually sold in sets of three, — taper, plug, and bottoming. See Fig. 76.

The cutting of a thread with a tap is not difficult, but requires care in the manipulation. The tap does not need to be forced into the work, since the thread will draw it forward. The taper-

TABLE OF TAPS AND CORRESPONDING DRILLS.

Tap. Diameter in Inches.	No. Threads per Inch.	U.S. Standard Drill Diameter.	V-Thread Drill Diameter.	Tap. Diameter in Inches.	No. Threads per Inch.	U.S. Standard Drill Diameter.	V-Thread Drill Diameter.
1/4	20	3/16	11/64	1 7/8	5	1 5/8	1 17/32
5/16	18	1/4	1 9/64	2	4 1/2	1 23/32	1 21/32
3/8	16	9/32	9/32	2 1/4	4 1/2	1 31/32	1 7/8
7/16	14	11/32	21/64	2 1/2	4	2 3/16	2 3/32
1/2	13	13/32	25/64	2 3/4	4	2 7/16	2 11/32
9/16	12	7/16	7/16	3	3 1/2	2 5/8	2 1/2
5/8	11	1/2	1/2	3 1/4	3 1/2	2 7/8	2 3/4
11/16	11	9/16	9/16	3 1/2	3 1/4	3 1/8	2 15/16
3/4	10	5/8	19/32	3 3/4	3	3 5/16	3 3/16
13/16	10	21/32	21/32	4	3	3 9/16	3 7/16
7/8	9	23/32	25/64	4 1/4	2 7/8	3 13/16	3 11/16
15/16	9	3/4	49/64	4 1/2	2 3/4	4	3 7/8
1	8	27/32	13/16	4 3/4	2 5/8	4 1/4	4 1/16
1 1/8	7	15/16	29/32	5	2 1/2	4 1/2	4 1/4
1 1/4	7	1 1/16	1 1/32	5 1/4	2 1/2	4 3/4	4 1/2
1 3/8	6	1 5/32	1 1/8	5 1/2	2 3/8	5	4 3/4
1 1/2	6	1 9/32	1 13/64	5 3/4	2 3/8	5 1/4	5
1 5/8	5 1/2	1 3/8	1 5/16	6	2 1/4	5 1/2	5 1/4
1 3/4	5	1 1/2	1 13/32				

ing of the tap has a two-fold effect. No one thread must do all of the work in the removal of the metal; each succeeding thread removes a small amount until the full thread has entered the hole. The second effect is that, as in the cases of a reamer, the tap is easily entered and started. Care must always be exercised at this point of the work. The taper of the tap allows it to easily enter the hole, and also makes it possible for it to enter at an angle. If

it is started in the latter condition, the thread will not be at right angles to the surface. The degree of care needed in the starting of the tap depends upon the job that is to be done. In the case of tapping a nut, it will usually be quite sufficient to set the tap by the eye. In finer classes of work, however, the tap should be set with a square. Start the tap into the hole, and place a square on the surface beside it in two positions at right angles to each other, and see that the tap stands parallel to the vertical blade.

When holes have been drilled that are to be tapped, a good way of setting the tap is to put a center in the drill spindle. Put the tap into the hole, and bring this center down into the center hole in the head of the tap; this will steady the latter while it is being started.

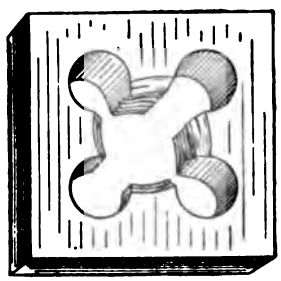


Fig. 77.

In using the tap, it is well to work it back and forth. This allows the chips to work clear of the cutting edges, and the oil to cover them. In case of heavy work, it is possible to drive the tap with the drill spindle, but when thus driving a tap in a machine, the backing off is impossible.

Sometimes a thread is to be cut down to the bottom of a hole that does not pass entirely through the metal. In this case the bottoming tap is used. This is a tap that is not tapered at the entering end. The method of working is to first cut the thread as far as possible with the plug tap, and then use the bottoming tap, which will then enter easily and can be driven to the bottom.

Machine tapping is best done by using a frictional tap-holder; that is, one in which the friction is enough to cut the threads, but which will slip when the tap strikes the bottom of the hole. This will insure the hole being tapped to the bottom, and avoid all danger of breaking the tap. To withdraw the tap, the machine is reversed, usually at a higher speed than used in tapping.

When tapping wrought iron and steel, a plentiful supply of

oil should be used. On brass the use of oil is unnecessary, while cast iron should always be tapped dry.

DIES.

Dies are used for cutting threads on bolts and other similar parts to be placed in holes which have been threaded by taps.

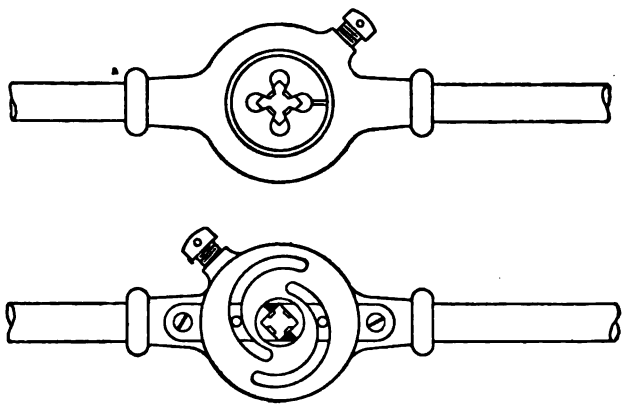


Fig. 78.

The general rules given for the use of taps apply to dies. As the number of threads in a die is much less than on a tap, and because the chips have a much freer exit, it is not as necessary to back up a die as it is a tap.

Dies for small work are usually made solid, as shown in Fig. 77, and often have a slight adjustment for altering the size. They cannot be sharpened, but have an advantage in readily centering on the work. As the full thread is cut at one passage of the die, it takes considerable power to operate solid dies of large size. For this reason, hand-operated solid dies are seldom used above one-half inch. The holder or die stock shown

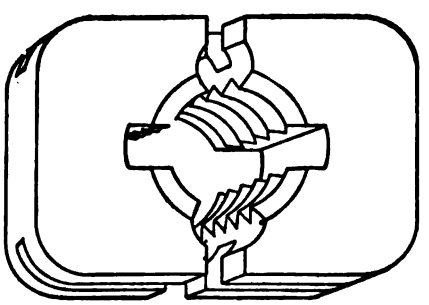


Fig. 79.

in Fig. 78 has a guide to hold the work at right angles to the die, but die stocks are often made without this convenience.

The split form of die, generally known as the jamb-die (shown in Fig. 79), can be easily sharpened, has unlimited adjustment for size, and cuts the thread by easy stages, as it were.

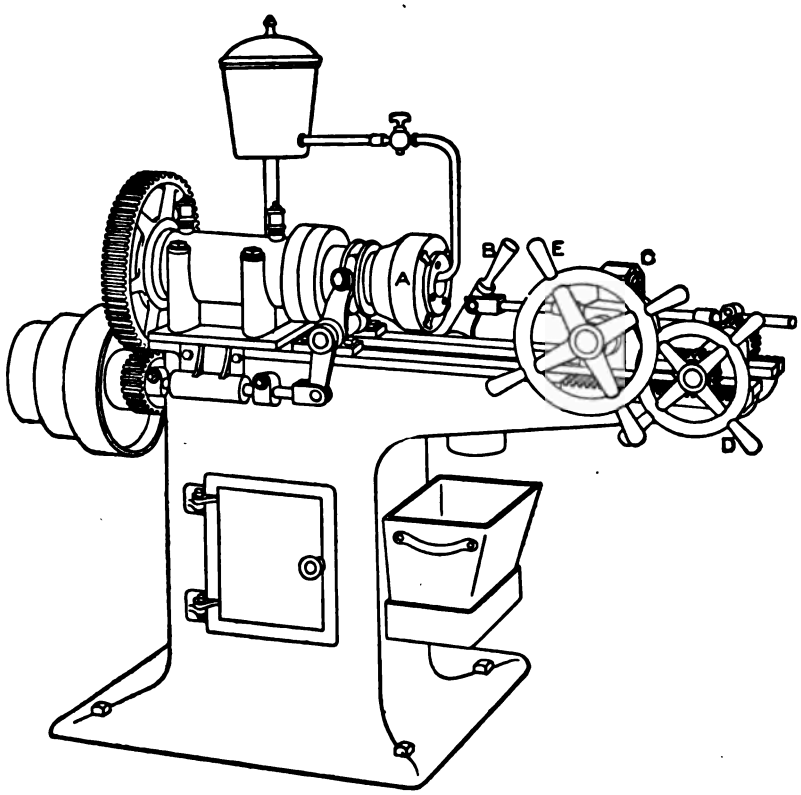


Fig. 81.

It is made in sizes up to two inches, and is for hand operation only. The holder for this form of die is called a screw plate, Fig. 81. These are not furnished with guides for the work.

Cutting Pipe Threads. Another common form of thread cutting is that on wrought-iron pipe. The pipe thread is rounded

slightly at top and bottom, and is made tapering at the rate of three-quarters of an inch per foot. The dies are usually solid, square in form, and the die stocks are provided with a ring,

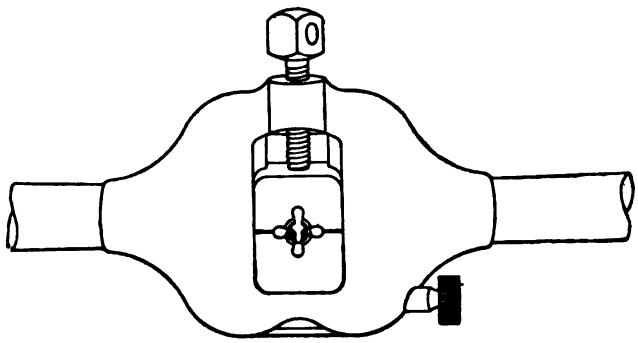


Fig. 80.

which fits over the pipe and serves to hold it square with the die. This avoids the danger of cutting the thread at an angle with the pipe axis.

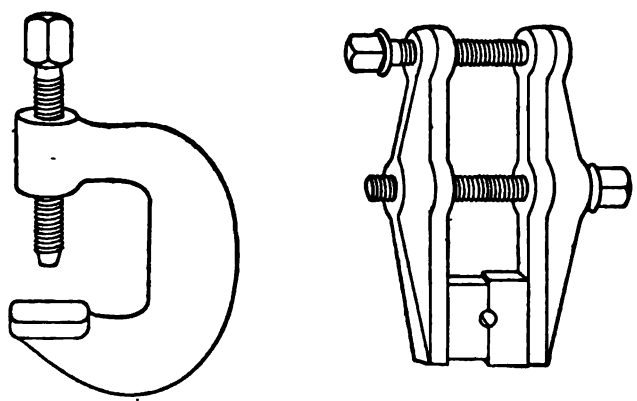


Fig. 82.

Comparatively little thread cutting is done by hand. A large proportion of all such work is performed on bolt-cutters. This is ordinarily the roughest and cheapest class of work, and the run-

ning of the bolt-cutter is usually the first work to which the apprentice is assigned.

Bolt-Cutter. An ordinary type of bolt-cutter is shown in Fig. 80. The dies are held in the head A. Instead of being solid, as in Fig. 77, they are made in sections, and can be opened or closed by the movement of the lever B. A chuck, C, is placed on a traveling head, and this can be moved back and forth by the hand-wheel D. The method of working is very simple. The dies in the head are closed in order to be in the working position. The bolt to be cut is gripped in the chuck by turning the handle E, and forced against the dies by the handle D. As soon as the dies have taken hold, they draw the bolt ahead. When a sufficient length of thread has been cut, the dies are opened and the bolt withdrawn. This avoids the necessity of backing out, as would be required if the dies were solid. While the thread is being cut, the dies are kept flooded with oil.

Templets. Where the same piece of work is to be many times repeated, templets are used. This method avoids the necessity of making measurements in the laying out of the work.

The *marking templet* consists of a piece of the same shape as the finished article. It is usually laid on a flat surface, and held fast by iron clamps as shown in Fig. 82. The outline is then marked on the surface with a scriber, and sometimes emphasized by prick punch marks.

The *filing templet* is of the same character as the one just described, but it is hardened. It is clamped in the vise with the piece to be shaped, and the surface filed down to coincide with the form of the templet.

Where holes are to be drilled in duplicate, a templet known as a *jig* is used. These jigs are made so that they fit over the piece to be drilled, and, when clamped in position, indicate the location of the holes by means of hardened steel bushings set in the templet.

The making of templets and jigs is one of the finest branches of the machinist's work, and is generally classed under the head of tool making. The rapid and economical production of machine parts in quantity depends largely on the tool maker, who must, therefore, be considered the highest type of machinist.

THE LATHE.

THE lathe is one of the most ancient of tools, and is a development of the potter's wheel. The spindle is horizontal and the work is revolved while the cutting tool is stationary. In its

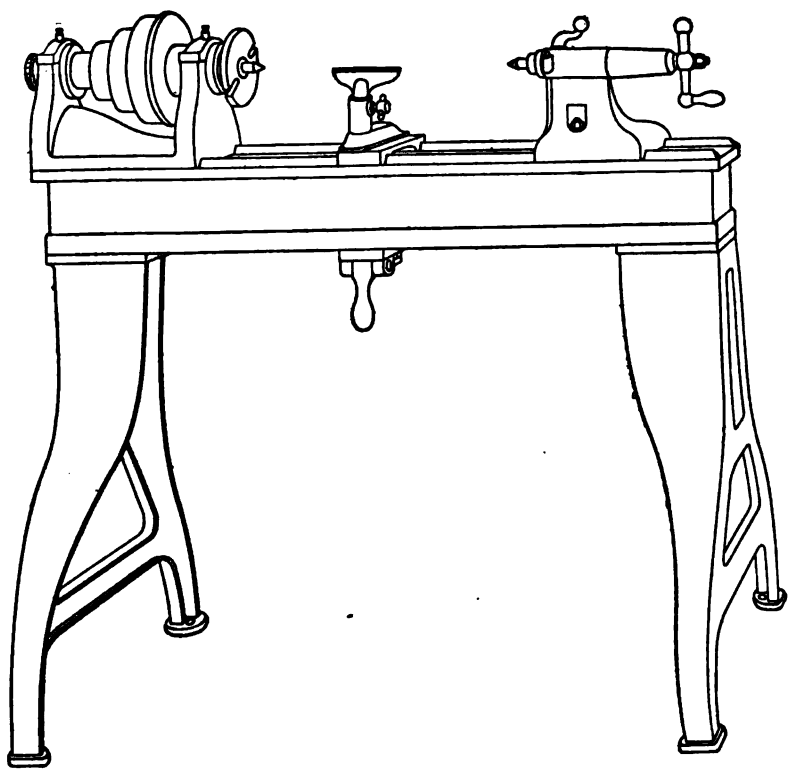


Fig. 33.

various forms and sizes it is by far the most important tool in the machine shop. It is built in a wide range of sizes from the delicate instrument suitable for the work of the jeweler to the great machine capable of turning engine shafts for the largest ocean

steamships or the rings for the heavy ordnance of battleships and fortifications.

Speed Lathe. The small lathe used in the machine shop for the operations of hand turning, filing, and polishing is called the hand or speed lathe, Fig. 83. This type driven by foot power is in great favor with amateur workmen. While hand turning is avoided as much as possible, it cannot be wholly eliminated, and a brief description of the tools used and the operations performed seems necessary.

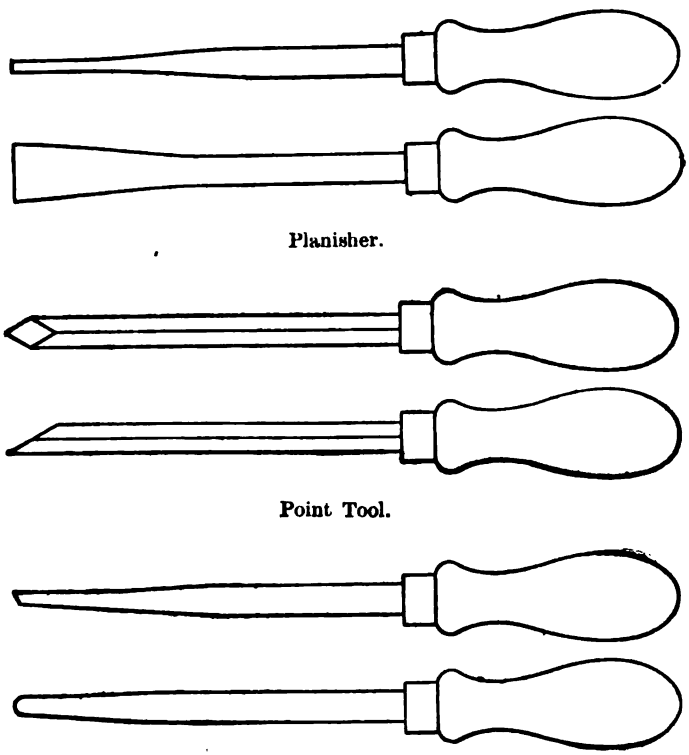


Fig. 84.

The tools used on brass and composition cut by a scraping action, and are almost always held at or below the center. The three tools shown in Fig. 84 called the planisher, point tool, and round nose, are typical of all the tools necessary for turning brass,

etc. The manner of holding these tools in connection with the T-rest is illustrated by the planisher in Fig. 85. Fig. 86 shows another view of the T-rest. Typical hand tools for cutting iron and steel are the diamond point or graver and the round nose,

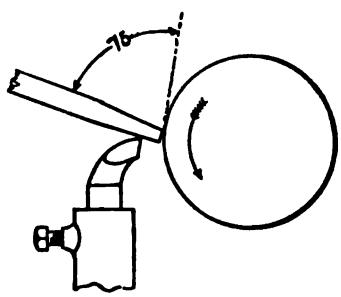


Fig. 85.

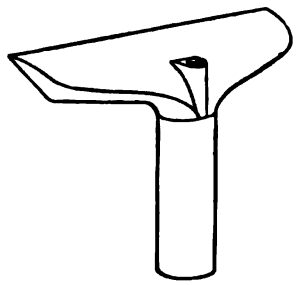


Fig. 86.

shown in Fig. 87. They are used differently from hand tools for brass, in that the cutting edge is carried above the center, and the metal is removed by cutting instead of scraping. The graver

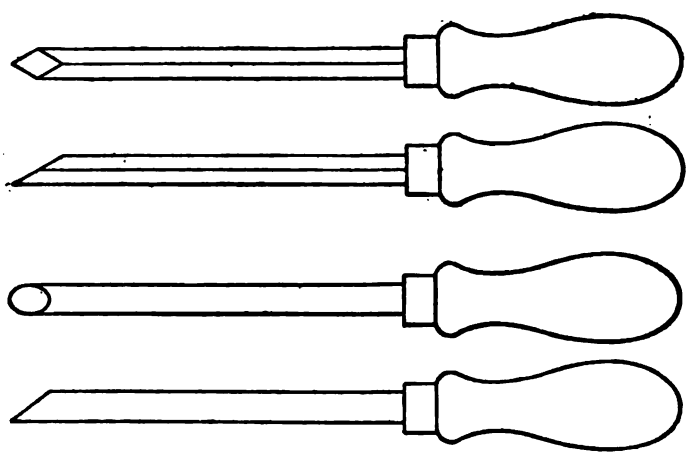


Fig. 87.

takes the place of the planisher and point tool, for it can be used as shown in Fig. 88, either on the outside or on the end of a piece of work. The round nose is used solely for concave surfaces, being held as high on the work as proper cutting will allow; Fig.

89. The graver can be used on brass for a great variety of operations; but its use, except in the hands of an expert workman, is attended with danger of catching in the soft metal and thus breaking the tool or spoiling the work.

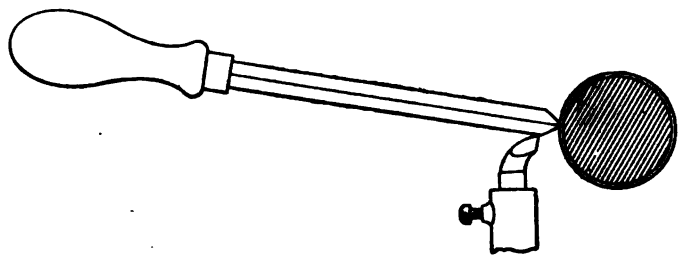


Fig. 88.

To make the hand lathe more rapid and certain in operation, it is frequently provided with a tool holder, called the slide rest, Fig. 90. This holds the tool rigidly and guides it mechanically, so that the work is done more rapidly than with hand tools. Slide rest tools are miniatures of those used on larger lathes, hence a description will not be given at this point.

Engine Lathe. When the slide rest is permanently attached to, and movable along, the bed of the lathe, and motion is automatically imparted to the tool, we have what is termed the engine lathe. This is one of the most common, as well as one of the most important machine tools, and one which can be made to serve for a wide variety of operations. For these reasons, it is entitled to a more extended description than that accorded to less typical forms.

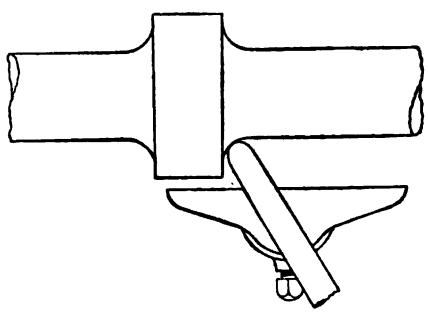


Fig. 89.

An ordinary form of screw cutting engine lathe is shown in Fig. 91, which is a representation of one of usual dimensions. It has a strong cast-iron bed A, carried on four well braced legs, that

also bored out and tapered at the end for a center G. This center is called the *live center* because it turns with the spindle. The *dead center* H is in the tailstock, and hence does not turn. At the left the spindle projects beyond the bearings, and carries a small cone pulley I and a pinion J. The cone pulley serves as the driving pulley for a narrow belt running to the corresponding pulley K on the feed rod N. The pinion serves to drive, through the intermediate gear M, the lead-screw O.

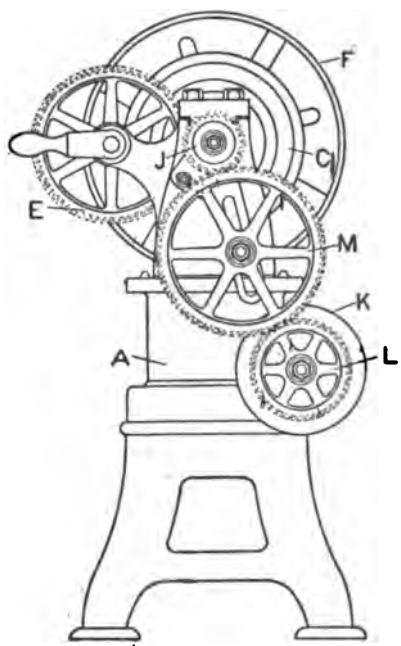


Fig. 92.

The work is held on the centers G and H, the distance between which is adjusted by moving the tailstock S (sometimes called the tailblock). The latter is held to the bed by a clamp and bolts tightened by the nuts T. To move the tailstock, these nuts are slackened and the stock moved to the proper position. The final adjustment is made by turning the hand wheel Q, which rotates a screw in the case P, which works in a nut in the spindle of the dead center H which is thus moved in and out. When the centers have been properly adjusted and the work is in position, the dead center is clamped by the handle R.

When work is to be turned, the tool is properly adjusted, and the carriage U moved along the bed. This movement is accomplished by means of gearing, which is placed behind the apron of the carriage, and driven by the shaft upon which the cone pulley K is keyed. The driving gear meshes with a rack beneath the upper ledge of the bed. Connection between the gearing and the shaft is made by a friction clutch. The carriage may also be moved by hand, by turning the hand wheel V, to which there is keyed a pinion directly meshing in the rack.

The tool is fed to the work and withdrawn from it by turning the cross feed handle W. This drives, by means of the screw and nut, the cross slide X. This arrangement permits any desired transverse or longitudinal position of the tool. The motion of the carriage is usually from right to left when at work. When screws are to be cut, a different feed is used. In ordinary turning there will be a variation in the relations between the rotation of the work and the longitudinal motion of the tool due to the slipping of the belt connecting the cone pulleys I and K, or to the slipping of the friction clutch connecting the shaft K to the driving gear.

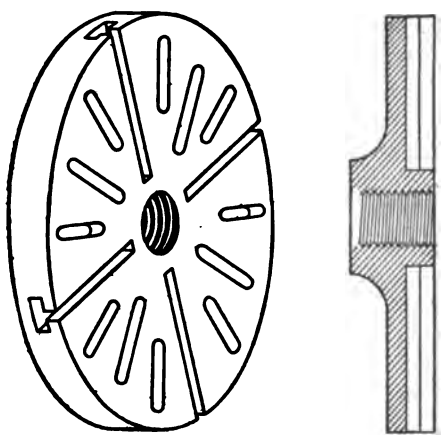


Fig. 93.

In order to cut a screw thread it is necessary that there shall be no change in the rotation of the work and the longitudinal motion of the tool. In other words, the tool must travel a given distance for every revolution of the work. To accomplish this, the carriage is driven by the lead-screw O working in a nut set in the carriage. The screw is, in turn, driven by the train of gears J, M, and L. The gear J is keyed to the spindle. The intermediate gear M runs loose on a stud. The gear L is keyed to the feed rod N, which transmits its motion to the lead-screw O by gears Y and Z. By changing the sizes of the gears used on the spindle and the screw, any desired thread may be cut. The size of the intermediate gear M has no effect on the thread being cut. It is used to connect the other two gears, and can be adjusted to any desired position for that purpose.

In this country the SIZE OF A LATHE is designated by the largest *diameter* it will swing over the guides, and by the length of the bed. The lathe illustrated is known as $24'' \times 8'$. In England the distance from the guides to the center is the unit of size, and, in a few cases, the greatest distance between centers is

considered to be the length of the lathe. Thus a 15-inch lathe in England would be a 30-inch lathe in the United States.

The attachments usually furnished without extra charge are a large face plate of the full swing of the lathe, a steady rest, and a follower rest.

The small face plate is used only for driving the work indirectly through suitable attachments. The large face plate shown

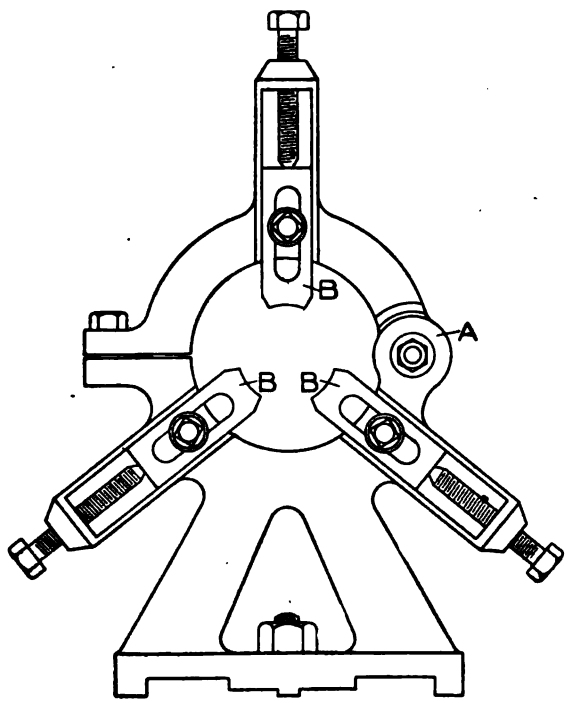


Fig. 94.

in Figs. 91 and 93 is used as a direct support for the work, the T-slots and other openings furnishing opportunities for bolting and clamping the work firmly to the face plate.

The Steady Rest. When work is being done on the end of a shaft so that the tailstock cannot be used, it is necessary to support the shaft in some other way. It is done by means of the steady rest shown in Fig. 94. This rest consists of a frame hinged at A, and fitted with three movable jaws, B B B. The rest is

clamped to the lathe bed in the proper place. The jaws B B B are then adjusted to form a bearing for the work, care being taken that the axis of the work is parallel to the ways, or shears. Unless it is parallel, the work will not be turned true; that is, the end

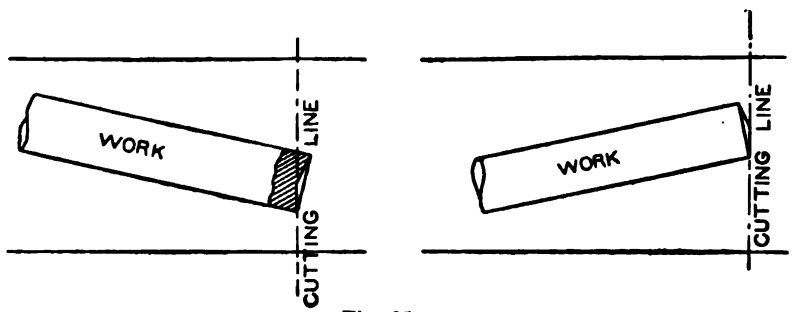


Fig. 96.

will not be square, but will be hollowed or conical, as shown somewhat exaggerated in the accompanying diagram (Fig. 95). The steady rest is also used to support long shafts that are being turned; it prevents such work from sagging at the center and thus being turned out of true.

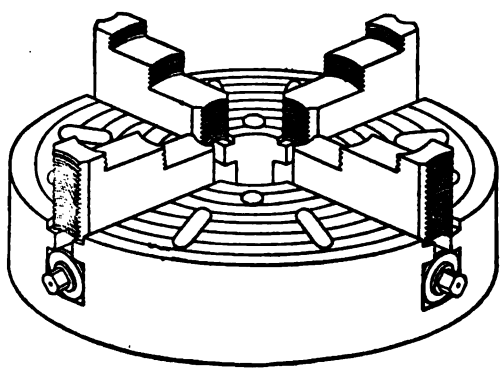


Fig. 97.

After adjusting the steady rest to size, it can be moved along the bed of the lathe without changing the relation to the lathe axis; but care must be taken not to reverse the steady rest in the lathe, as, in most cases, such action would necessitate a readjustment.

The names, back rest and center rest, are synonymous with steady rest, the use of the device often determining the name.

The follower rest serves some of the purposes of the steady rest, but is fastened to the carriage, and moves with it at the point of greatest stress. It may consist of adjustable jaws or a solid ring to slip over the piece being turned. It is especially

valuable in turning shafting and other work where the ratio of length to diameter is very great. The follower rest is not very often used in shop practice, except on classes of work just mentioned. The extra attachments desirable for a lathe will now be briefly described.

Chucks. First in importance is the lathe chuck, Fig. 96. It consists of a body which is fastened to a special face plate in such

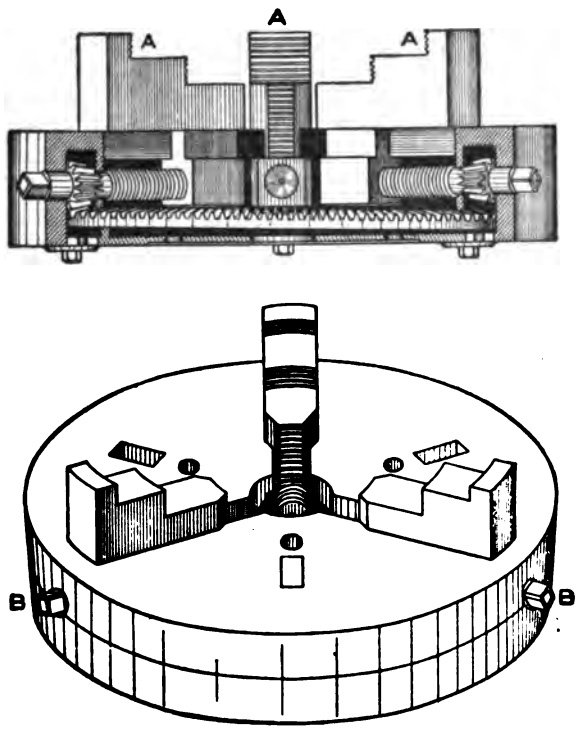


Fig. 96.

a way that is concentric with the spindle. The three jaws AAA can be moved in and out toward the center by turning the screw-heads BBB. These chucks are universal or independent. In the universal chuck all of the jaws are operated simultaneously. That is, when one of the screw heads B is turned, all of the jaws are moved an equal distance towards or away from the center. This makes it possible to put the work in position quickly if it is approximately round in its unfinished condition. With the in-

dependent chuck, Fig. 97, each jaw is operated separately. Such a chuck is used for holding pieces of irregular shape and those which must be held eccentrically. Frequently the universal and independent chucks are combined in one. Means are then provided for working the jaws separately or together as desired.

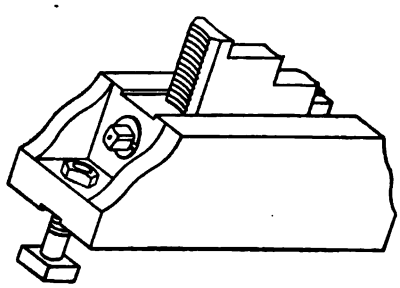


Fig. 98.

In using the universal chuck each screw should be tightened. The method of procedure is to place the work in the chuck, and turn one screw head until all of the jaws are in contact with the piece to be operated upon. Then turn the chuck and tighten each screw head successively until each one is tight enough. Owing to wear and lost motion, it is sometimes necessary to apply the wrench to each one three or four times before the final adjustment is reached.

Lathe chucks are usually made with three or four jaws. Universal chucks generally have three jaws, while independent chucks have four. It follows that a combination chuck is not wholly satisfactory, because with three independent jaws it is very difficult to adjust work accurately, and with four universal jaws it is equally difficult to get every jaw to bear on the work. For certain classes of work, especially valves and pipe fittings, chucks with two jaws are often used.

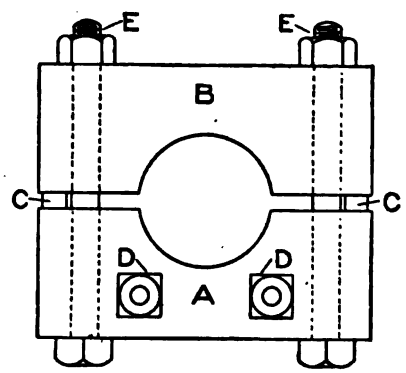


Fig. 99.

The large face plate of a lathe can be made into an independent chuck by attaching what are known as face-plate jaws; Fig. 98. In this case, there may be six, eight, or more jaws.

As these chucks are expensive it sometimes happens that a

piece is to be held for which no provision is made. A chuck can then be made of wood. Such a chuck is shown in Fig. 99. Two pieces of wood, A and B, are bolted together by the bolts EE, while separated by the filling pieces CC. The piece is firmly bolted to a face plate by the bolts DD. The lathe is then run at high speed, and the interior bored out exactly the size of the piece that is to be held. The nuts of the bolts EE are slackened and the filling pieces CC removed. The work is then inserted,

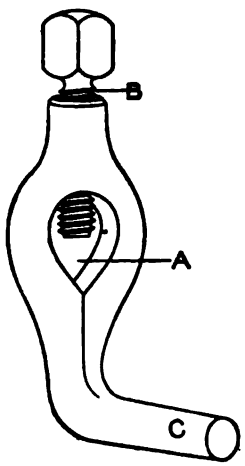


Fig. 100.

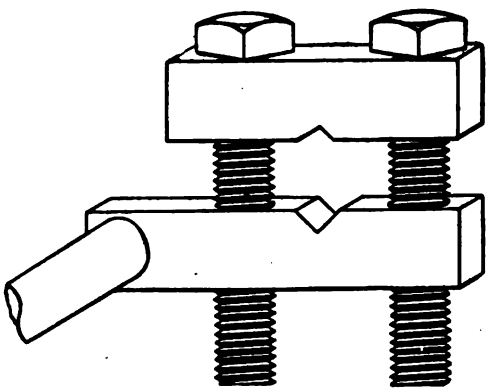


Fig. 101.

and by tightening the nuts EE, it is securely clamped between the pieces A and B.

Lathe Dogs. As the frictional contact of the work on the live center is not sufficient to turn it, some device must be used to make the work turn with the center. To accomplish this a lathe dog is used. For round work, such as shafting, a dog like that shown in Fig. 100 is often used. The shaft or piece to be turned is placed in the hole A, and held firmly in place by the set screw B. The tail-piece C is put through a hole in the face plate and the work rotates with the live center.

While this type of dog is satisfactory in most cases, the fact that the contact between the dog and the face plate is beyond the end of the piece, introduces a bending strain which is appreciable

in slender work. To avoid this, dogs are made with a straight tail, and driven by a stud projecting from the face plate.

For work other than round, a dog such as that shown in Fig. 101 may be used. The work is placed between the jaws, and held in position by the bolts. The holes in the jaws are made

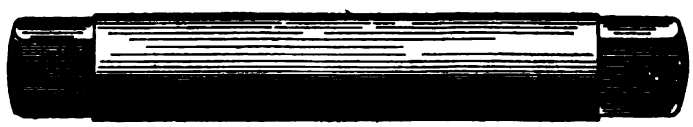


Fig. 102.

larger than the bolts, in order that the angle between the jaws may be varied. The connection between the face plate and dog is made as with Fig. 100.

Mandrels. Another method of holding work is by the use of a mandrel. This is a piece of steel with a slight taper; the ends

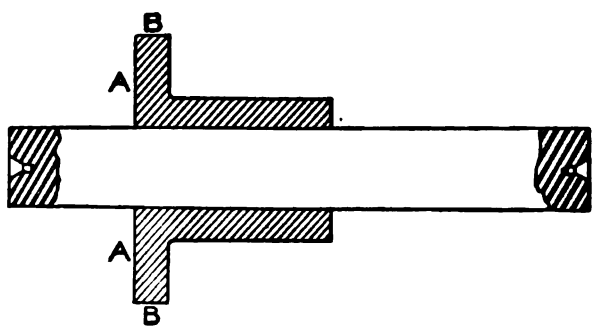
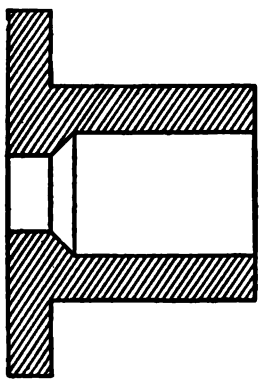


Fig. 103.

are flattened for the lathe dog, as shown in Fig. 102. It frequently happens that a piece with a hole in it is to be turned or finished over its outer surface. In this case a dog cannot be used, and it is troublesome to hold it to a chuck. Such a piece is shown in Fig. 103. This is a stuffing-box gland. If it were to be held by the jaws of a chuck the face A could not be reached at all, and only a portion of the edge B, whereas a dog clamped to it would offer even greater obstruction. The method of using the mandrel is to ream the gland out, so that it can be driven upon

the mandrell. When this has been done the frictional resistance between the two will be sufficient to drive the piece. In this manner it can be finished over its whole surface with but one setting in the lathe, so that all finishing possible may be done while it is in the chuck, leaving, in this case, only the face A and edge B to be finished while on the mandrel.



Should the gland be shaped, as shown in Fig. 104, it would be necessary to make a special mandrel to fit the bore. The cylindrical part of A of the mandrel must be a driving fit, and the part B a loose fit.

Expanding Mandrels. Where a mandrel like that shown in Fig. 102 is frequently used, the constant driving on and off of the work will wear it to a smaller diameter, causing it to become useless. Again, solid mandrels are usually made of standard diameters, varying by sixteenths of an inch. It sometimes happens that a piece to be turned has a hole which will not fit any standard solid mandrel.

Fig. 104.

To overcome these difficulties an expanding mandrel, shown in Fig. 105, is used. This is really a chuck so arranged that the grips can be forced out against the interior of the hole. When the work has been finished the grips are again drawn in and the piece removed. Another form of expanding mandrel is shown in Fig. 106.

Centering. A piece to be turned is supported on the two centers of the lathe. In order that this may be done, the ends are prepared by drilling a hole in each and countersinking it. This is called centering the work. The countersink should be of exactly the same angle as the lathe center upon which it is to run. The hole should be drilled deep enough so that the point of the lathe center may not strike. The shape of the hole is

shown in Fig. 107. The angle of the hole varies from 40° to 90°, but 60° is the generally accepted standard. The effect of using a 60° hole on a 90° center is shown in Fig. 108. The result of such an application is that the bearing will be concentrated on a

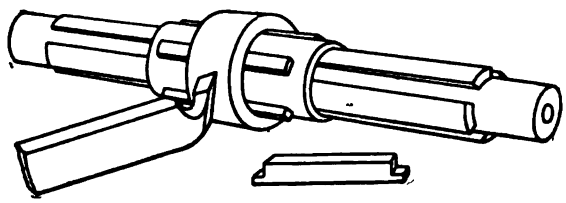


Fig. 105.

line AB causing rapid wear of the outer end of the hole, and a cutting of the dead center.

The size of center holes varies with the weight of the work and the character of the operation. Heavy work and rough turning require large center holes, while small work and fine turning can be done without countersinking deeply. As bearing surfaces in cast iron must be large to be satisfactory, center holes in cast iron are likely to give trouble by unequal and rapid wear. When turned work in cast iron must be very accurate, it is well

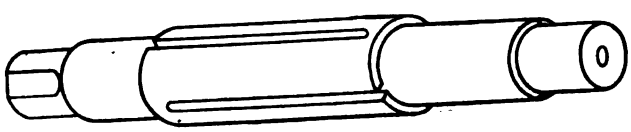


Fig. 106.

to drill a large hole in each end, drive in a plug of wrought iron or mild steel, and form the center holes in the plugs thus driven.

When the piece has been put in place, the dead center should be oiled and screwed up into position. It should be tightened so that there is no lost motion and yet allow the work to turn freely.

The turning of shafts and bars is not, however, the only kind of work to be done on a lathe. Pieces are to be turned that are thin, that have holes through the center, and which are so shaped

that they cannot be held upon the centers. In such cases it becomes necessary to hold the work firmly without distortion, as may be done by use of the lathe chuck.

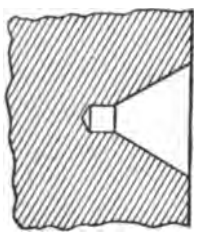


Fig. 107.

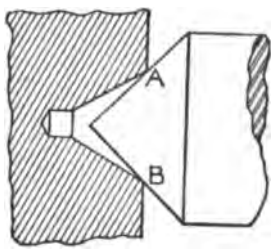


Fig. 108.

Still another method of holding work is that shown in Fig. 109. The piece is clamped to the face plate. When this is done there should be a bearing on the face plate immediately beneath the clamping strap. For example consider Fig. 110. Suppose a disk having four feet on one side is to be faced off on the front.

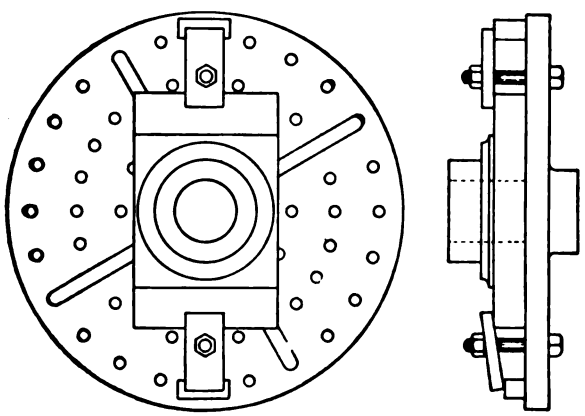


Fig. 109.

The clamps should be placed directly over the feet as in B. If they are placed between the feet at EE the work will be sprung out of shape as shown by the dotted lines in A. Then, when the tool has done its work the shape of the piece, while bolted to the

face plate, will be as shown in C. As soon as the pressure of the straps is removed the elasticity of the metal will cause the piece to assume the convex form shown in D, whereas, if the straps had been placed as shown in B, no distortion would have been produced.

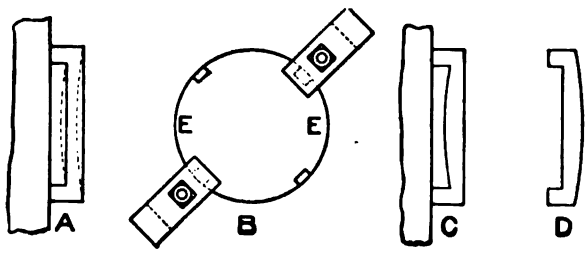


Fig. 110.

An angle iron may be clamped on a face plate, as shown in Fig. 111, presenting a surface parallel to the lathe axis to which work may be attached. The angle irons may of course be at any angle to the face plate, but 90° is the one most commonly used.

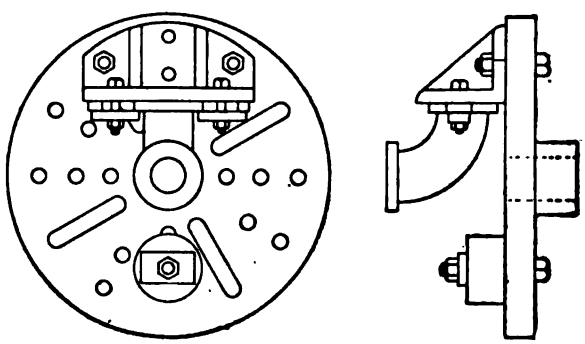


Fig. 111.

When work is held in this manner, it is desirable to counterbalance it, as is also shown in Fig. 111.

Adjusting Pieces to Center. Whenever a piece is to be turned in a lathe it is necessary to adjust it so that its rough outline is approximately concentric with the lathe centers. This is

done by bolting it lightly to the face plate and running the lathe. While running, a piece of chalk is held so that the projecting portions will strike it. This marks the piece, and indicates the part that is *farthest* from the center. The lathe is then stopped and the piece shifted, *moving the chalk mark towards the lathe center.* This is repeated until the chalk makes a continuous mark around the whole circumference. The piece may then be considered to be centered.

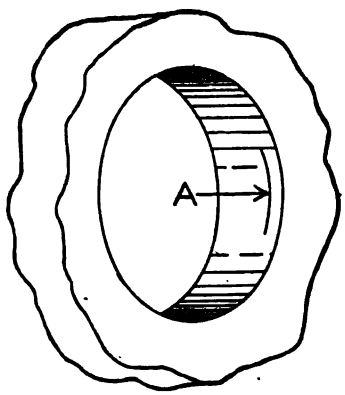


Fig. 112.

Suppose it is necessary to center a piece having a hole that must run true. In this case the inside of the hole must be used as a guide. Let Fig. 112 represent the hole with the thin shell, and A a chalk mark made as described for centering by the outside. In this work the *chalk mark must be moved away from the center.* A lathe tool may be used as shown in Fig. 113 to center a piece that is to be bored.

Where a piece has already been turned, greater accuracy is demanded, and a surface gage may be used to advantage. Set the gage on the bed or carriage of the lathe, and place one of the points in contact with the work. Rotate the work as before, and note where the point touches the surface. This point is to be treated in the same way as the chalk mark explained in a preceding paragraph.

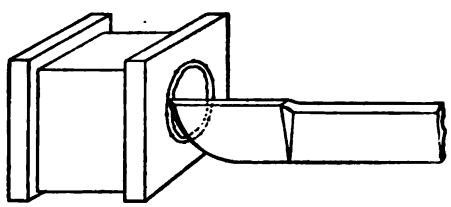


Fig. 113.

A still more accurate method of centering a piece of turned work on a face plate is to use some form of graduated indicator, such as the Starret indicator, Fig. 114. This is held in the tool post, and the contact point brought against the work until the indicating arm is at zero. If the work is now slowly rotated by

hand, the indicator will show just where the work is out of true, and being graduated in thousandths of an inch, will also show how much. By careful adjustment, the piece may be centered to the degree of accuracy required.

Instead of locating a cylindrical surface concentric with the axis of the lathe, it often happens that a point is to be located in the axis. For this purpose, the center indicator, Fig. 115, is used. The free end of the short arm is placed in the point to be centered (usually a prick punch mark), the fulcrum being held in

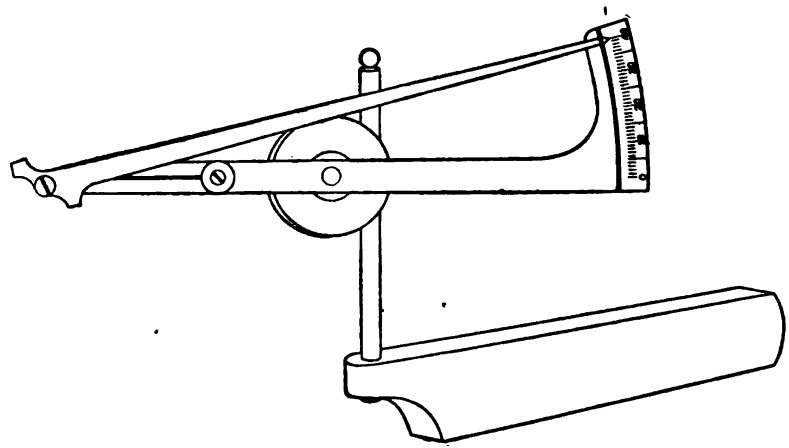


Fig. 114.

the tool post; when the work is rotated, the free end of the long arm not only shows the error, but magnifies it in proportion of the length of the short arm to the length of the long arm. By using a comparatively long arm, the point can be very closely centered.

Centering Finished Work. After making the center punch mark in the end of the piece, it is drilled and countersunk. This must be done very accurately, but frequently the drilled hole or the countersink will not be in the exact center. See Fig. 116. This may be caused by uneven grinding of the drill, eccentric motion of the drill point (due to the inaccurate running of the spindle), or the distortion of the metal by the center punch. If the countersink is not exactly in the center, it must be drawn back to the center. This is generally done by the small round-

nosed chisel and a hammer. The method of doing this work is as follows: After making the center punch mark, the hole is drilled and then countersunk slightly. The work should now be

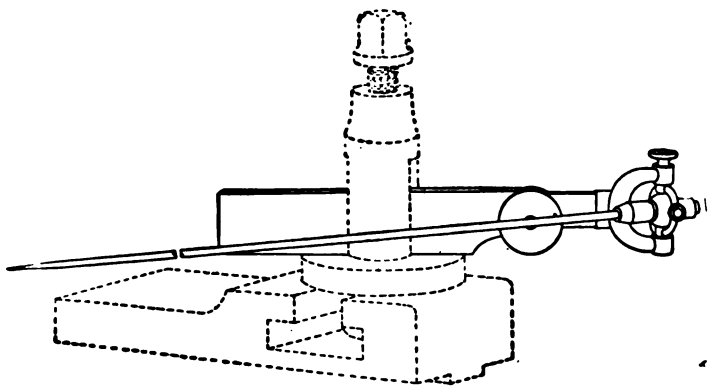


Fig. 115.

stopped; and if the circumference of the conical hole is not concentric with the circumference of the piece a groove should be cut down the side farthest from the outer circumference, as shown in Fig. 117. The depth of the groove, which should be near the

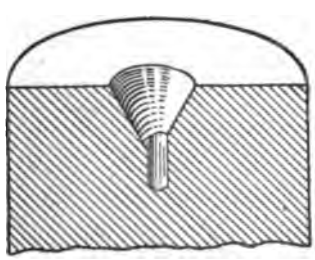


Fig. 116.

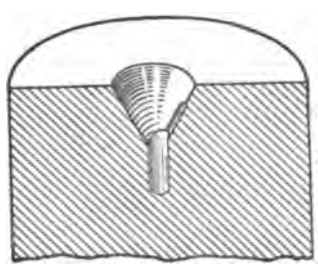


Fig. 117.

center, depends upon the amount of eccentricity. The countersink is again started and the groove drilled out. If the circle is not yet concentric, the process is repeated.

Lathe Tools. The cutting tools used in lathes are of a great variety of shapes. These shapes are adapted to the work that is to be done, and to the kind of finish that is to be left upon the

metal. There are two fundamental requirements that all tools must fulfill: *The cutting edge alone must touch the metal; the edge must be keen.* A typical form of tool is shown in Fig. 118. The cutting edge of the tool at A is in contact with the work. The bottom line A B runs back from the metal and does not touch it. The top face A C slopes down and back. The line A D is a tangent at the cutting point, and the line A E is radial at the same point. Therefore, the angle D A E is always a right angle or 90°. The angle D A B is called the angle of *clearance*, and should be small; in lathe tools, not over 10°. The angle C A E is called the angle of *rake*, and should be as great as circumstances will permit; about 20° on lathe tools for wrought iron and steel, leaving 60° for the *solid* or *cutting* angle, which is the same angle as is used for a cold chisel.

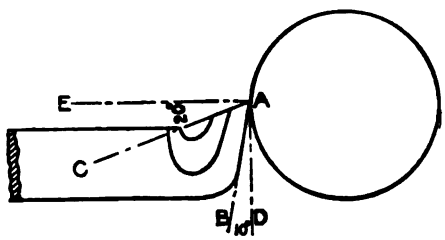


Fig. 118.

Clearance prevents the tool from rubbing on the work, while rake adds to the keenness of the cutting edge, and gives freedom

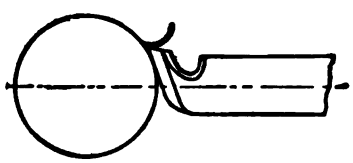


Fig. 119.

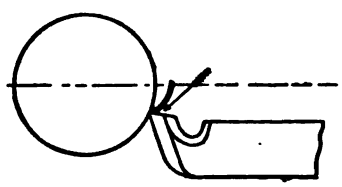


Fig. 120.

to the removal of the chips. A tool should have sufficient strength at the point to do the work required.

The tool should be set so that the cutting edge will be very nearly at a horizontal line, passing through the axis of the work. Many machinists set the cutting edge a little above the horizontal line. When so set the stress tends to force the tool down along the line of its greatest strength. The tool may, however, be set

too high. If this is done, as in Fig. 119, the angle of clearance will disappear, and the curve of the work will rub against the bottom of the tool. This will tend to force it out; it will heat the steel and produce a rough surface on the metal being turned. If, on the other hand, the tool is set too low, as in Fig. 120, the cutting edge does not stand in line with the motion of the work at the point of contact. The result will be that the metal will be scraped rather than cut, as there is no rake, and the pressure upon the tool will be in the line of its lowest power of resistance, as indicated by the arrow. Such a position might cause the point of the tool to break off. It will also cause the tool to tremble or chatter as it removes the chips, leaving a rough and wavy surface on the metal.

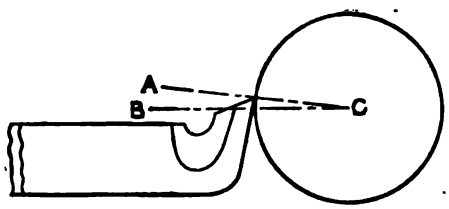


Fig. 121.

As stated above, many machinists prefer to set the cutting edge a little above the center; if this is done, the rotation of the work

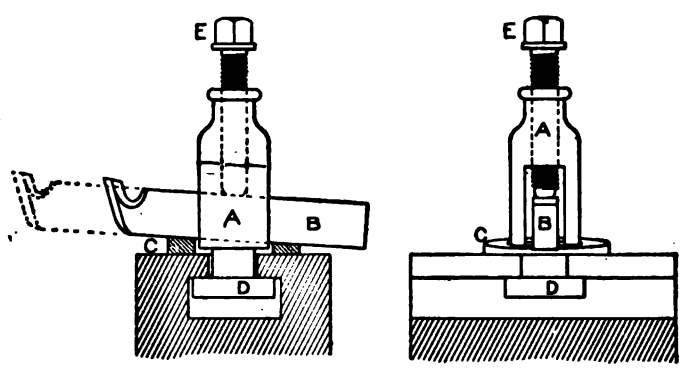


Fig. 122.

has a tendency to depress the point of the tool a little, bringing it, while cutting, nearly to the center. The amount the tool is set above the center is slight, and of course depends upon the character of the work. The angle A C B, Fig. 121, should be only about 5 or 6 degrees.

The tool is usually held to the carriage by means of a tool post, shown in Fig. 122. The post consists of a piece with a slotted hole through the center for the tool B. A ring C slips over it and rests upon the body of the carriage. This ring may be beveled as shown, to provide vertical adjustment for the point of the tool. The post has a collar D at its lower end that goes loosely into a slot in the carriage. At the top there is a set screw E. When the tool has been properly adjusted by turning the ring C to give it the correct elevation, the set screw is tightened down upon the top of the tool. This raises the tool post to a bearing on the under side of the slot, and clamps the whole carriage firmly in position.

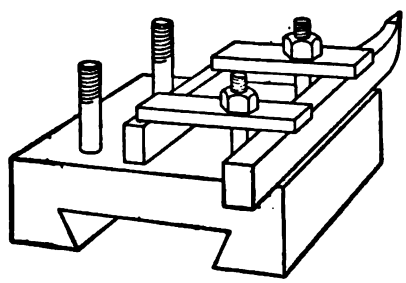


Fig. 123.

In setting the tool, it should be done with the cutting edge as far back towards the supporting ring as possible. If it has too much overhang, as shown by the dotted lines of Fig. 122, it will spring under the pressure of the work and chatter.

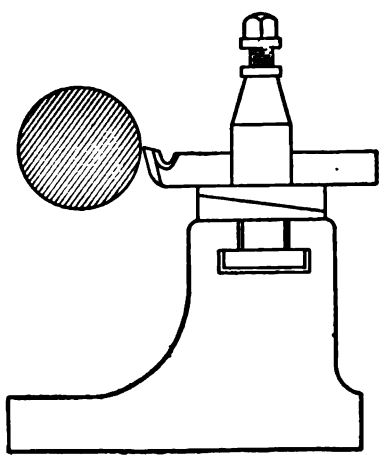


Fig. 124.

While this form of tool post is used more than any other, there are certain objections to it. In the first place, changing the height of the tool point also changes the angles of rake and clearance. These are supposed to be correct when the base of the tool is horizontal. Any change from this position alters the sizes of these angles materially. Again, this post is not rigid enough for heavy work. On lathes of over thirty inches swing, the style of tool-holder shown in Fig. 123 is often employed.

English manufacturers use it almost exclusively on all sizes. There is no provision for raising and lowering the point of the tool; and while this is not of serious importance on large lathes, 30-inch and over, it becomes a matter of moment when turning such work as is usually handled in lathes of 14-inch and 16-inch swing.

The form shown in Fig. 124 has two beveled rings to adjust the height of the tool.

The Lipe tool post, shown in Fig. 125, combines the good points of all the other forms; the tool can be held by one or two

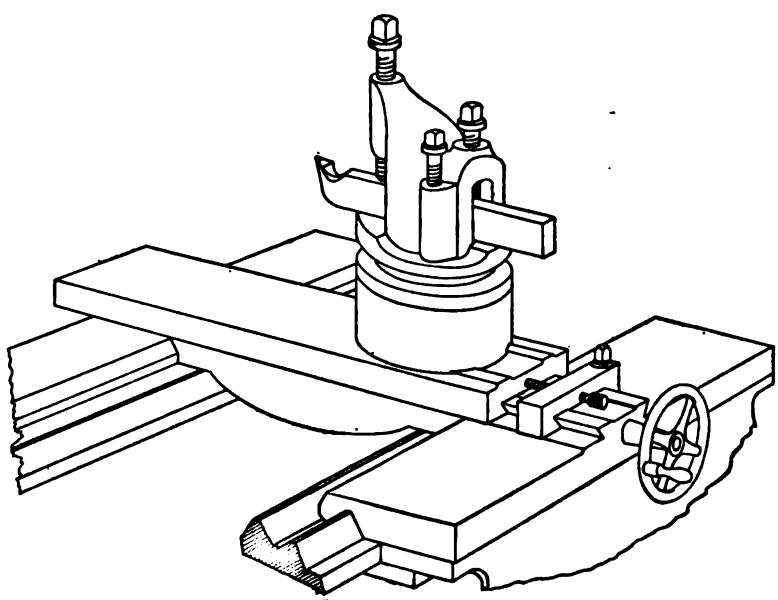


Fig. 125.

screws as the character of the work may require, and the tool may be adjusted vertically and horizontally after being clamped down. The construction and operation of this tool post are so evident from the illustration, that further description will not be given.

An entirely different method of adjusting the tool point is by means of what is called the elevating or rise and fall rest shown in Fig. 126. In this type there is a T-shaped casting carried on the upper part of the carriage, supported by trunnion screws at

the front, and by an adjusting screw at the rear. With this is used a tool post as shown in Fig. 122 with a plain ring. The elevating rest is used quite extensively on small lathes, but the convenience of adjustment is gained by a loss in rigidity. The cross rail is light, and the elevating portion, being supported at three widely separated points, lacks stiffness. As the effective swing over the carriage is limited by the height of the cross rail and the parts carried above it, they are made light — too light in many cases.

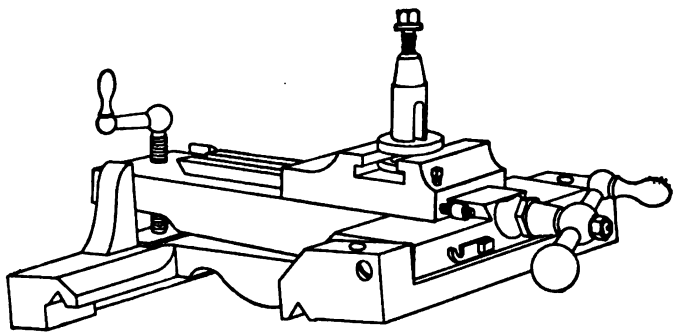


Fig. 126.

Turning Tools. The side or facing tool, Fig. 127, is the most common form of lathe tool. It is used for squaring up the ends of shafts, facing shoulders, and similar work. While the ordinary forms will not remove a large amount of metal, they can,

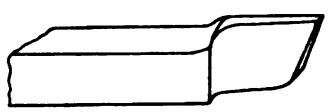


Fig. 127.

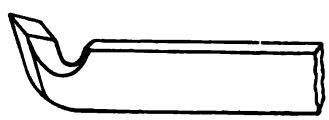


Fig. 128.

when made thick and heavy, be used for roughing cuts on the surface of cylindrical work. The common form is made slender in order to work between the dead center and the work in squaring up ends.

A common form of tool for turning wrought iron and steel is the diamond point shown in Fig. 128. The name is derived from the shape of the top face. This tool has both front and side rake

which allows a keen edge without reducing the strength. It is used for finishing only when the point is ground slightly rounding and a fine feed is used. In finishing, but little metal should be removed. The *Feed* of a tool is the amount of longitudinal advance at each revolution of the work. For roughing out cast iron, a strong and rapid working tool is a round nose with considerable side rake. For finishing wrought iron and steel, a modification of the diamond point, as shown in Fig. 129, is often

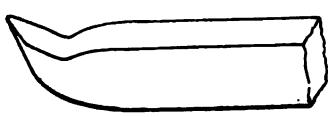


Fig. 129.

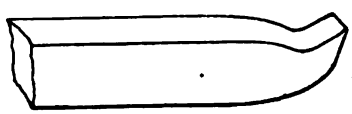


Fig. 130.

used. For cast iron, a square-nosed tool, Fig. 130, should be used. It must be carefully ground and accurately set, otherwise it is very likely to gouge into the softer parts of the metal. When finishing wrought iron and steel, the tool should be liberally supplied with oil or soda water. Cast iron must always be worked dry, both in roughing and finishing.

The cutting-off or parting tool is illustrated in Fig. 131. The blade is quite narrow; as narrow, in fact, as the character of the work will allow. This is necessary in order that the stock may not be wasted. As the blade must be narrower at the shank

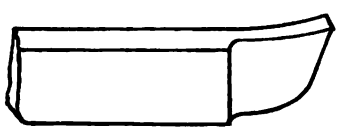


Fig. 131.

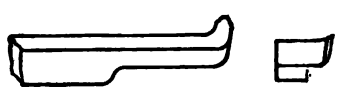


Fig. 132.

and at the bottom than it is at the cutting edge, it follows that the tool is weak. It must be set horizontally so that, as the tool is fed to the work, the cutting edge only will touch the metal. It must also be set so that the cutting edge will pass through the axis of the work as it is fed to the center. If set too high, it will cease to cut before the center of the work is reached, while if too low, the tool has a poor scraping action, and will leave a portion of the work uncut. On work held between centers, one should not

attempt to cut to the center of the piece, as the work will surely ride up onto the tool.

Boring Tools. When a hole is to be bored in a lathe, tools of a different shape from those used in turning must be used. The general form of the tool is shown in Fig. 132. The length of the shank at A depends on the depth of the hole to be bored, for it must be long enough to reach from the tool post to the bottom of the hole. This overhang makes the tool more likely to spring, and necessitates a much lighter cut than can be taken when removing the same amount of metal by outside turning tools. The result of this lighter cut is seen in the increase of time required to remove a given amount of stock. The shape of the cutting edge is practically the same as that of the tools for turning, except that the boring tool must have more clearance to avoid striking the work. Therefore, with the same solid angle, the tool will have less rake. The reason for this will be seen by compar-

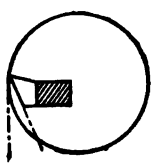


Fig. 133.

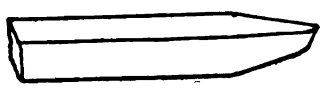


Fig. 134.

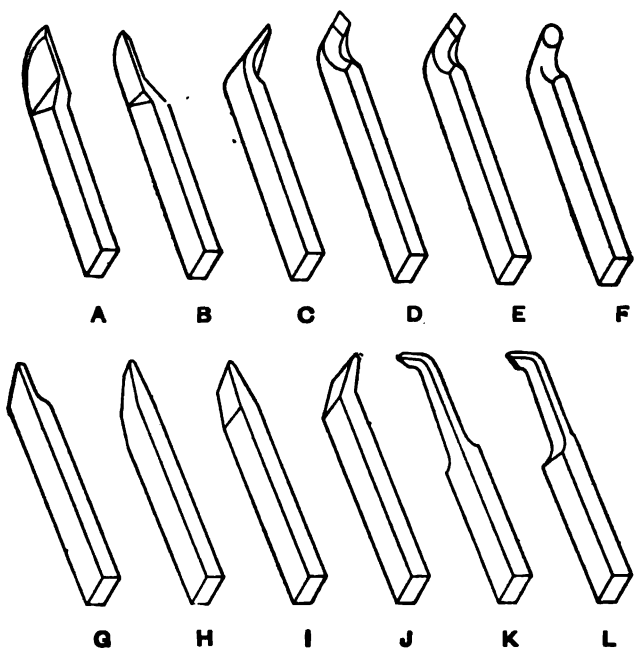
ing Figs. 118 and 133. In Fig. 118 it will be seen that the surface of the work is outside a tangent at the cutting point, and can never interfere with the bottom of the tool. In Fig. 133 the work surface is inside the tangent; and, unless the tool has a large amount of clearance, it will cause trouble by striking the bottom of the tool.

Tools for brass differ from those used on steel and iron in that they have no rake. A tool suited for brass is shown in Fig. 134. Brass is a very brittle metal, and the chips break off as soon as started from the main body. When turning wrought iron and steel, on the other hand, the metal does not break, but forms long spiral chips if the tool is in good condition. If a tool with rake is used in turning brass, the work will not only be rough in appearance, but there is great danger of the tool gouging into the stock and spoiling the work or tool, possibly both. The finishing

tools for brass may be square or round nosed, without rake; in fact, a small amount of negative rake will produce a much better surface. When the brass contains a large percentage of copper, some rake may be required owing to the ductility and toughness of the metal.

Fig. 135 shows common forms of lathe tools.

The shape of the tool has a very important influence on the amount of work it can be made to do. As has already been ex-



A Left-hand Side.
B Right-hand Side.
C Right-hand Bent.
D Right-hand Diamond Point.
E Left-hand Diamond Point.
F Round Nose.
G Cutting off.
H Roughing.
I Threading.
J Bent Threading.
K Boring.
L Inside Threading.

Fig. 135.

plained, these shapes vary with the different metals that are being worked, and also with the class of work performed. It is highly important that the cutting angles be correctly formed. While hand grinding on the emery wheel and grindstone is fairly satisfactory, the best results can only be attained by the use of a regular tool-grinding machine. In addition to such grinding, lathe

tools for fine finishing should be carefully whetted on a fine oil stone.

The cutting speed is an important matter. This varies with the shape of the tool, the quality of the metal being worked, and the strength of the lathe. The amount of metal removed in a given time is, therefore, equally variable. It is impossible to make a correct estimate of the time that a given piece of work will require unless all of the above elements are known. For approximate estimates, the speeds of cutting tools may be taken to range about as follows:

In cast iron,	from 30 to 40 feet per minute.
In wrought iron,	from 25 to 30 feet per minute.
In steel,	from 15 to 25 feet per minute.
In brass,	from 60 to 100 feet per minute.

Suppose a wrought shaft 6 feet long and 4 inches in diameter is to be turned. Let the lathe be capable of carrying a feed of $\frac{1}{32}$ inch per revolution. The shaft has a circumference of $4 \times 3.1416 = 12.5664$ inches. To give the tool a cutting speed of 25 feet per minute, the shaft must make $\frac{25 \times 12}{12.5664} = 24$ (about) revolutions, giving a feed of $\frac{1}{32} \times 24 = \frac{3}{4}$ inch in that interval of time. At $\frac{3}{4}$ inch per minute, it will take $(6 \times 12) \div \frac{3}{4} = 96$ minutes to take a cut the whole length of the shaft. The amount of feed is really the governing element. This may be as much as $\frac{3}{16}$ inch per revolution, and, for finishing cuts, may not be more than $\frac{1}{100}$ inch. The depth of the cut also influences the time required to finish a given piece. This may vary from $\frac{1}{100}$ to $\frac{1}{2}$ inch. All depends on the shape of the tool and the strength of the lathe.

The cutting speeds given above are what may be used with the best grades of tool steel, such as Jessop's, but by using air-hardening or tungsten steels, the speed of cutting may be very much increased over the values given above. These high-speed steels are rapidly coming into favor, more especially for heavy roughing cuts. Not only are the cutting speeds increased, but the chip is made heavier both in depth and feed up to the point where the lathe refuses to carry the load. The ability of this quality of steel to stand high temperatures without injury is the feature which enables it to do work at this rate.

For cooling the tool while performing heavy duty, a solution of sal soda is preferable to water, as it prevents rusting of the work and machinery. The lubricant does not assist in the severing of the metal; even with a most liberal supply, it is doubtful if any ever reaches the point of the tool. Its office is simply to

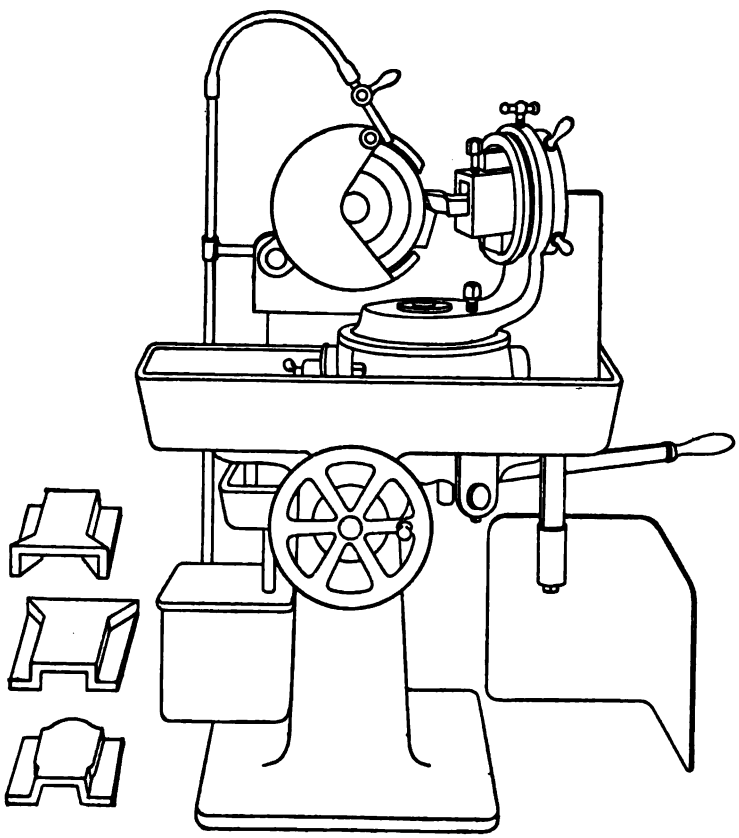


Fig. 136.

keep the tool cool. If a tool becomes overheated, the edge begins to turn over and it becomes dull.

Referring to Fig. 120, it will be seen that the chip, as it is being removed, presses down on the top face of the tool. This pressure increases with the depth of cut and the feed. The friction would soon cause a high temperature in the tool if it were

not relieved by the lubricant. The lubricant cools the tool by absorbing a portion of the heat, and lessens the amount of heat developed by reducing the friction between the tool and the chip. Clean, pure water is the only lubricant which can be used on cast iron, but the rapid rusting which follows its use makes it undesirable. Brass is also usually turned dry. Prime quality lard oil is sometimes used for cooling the tool; but the greater cost prevents its extended use, unless some means are provided to collect, separate, and filter it.

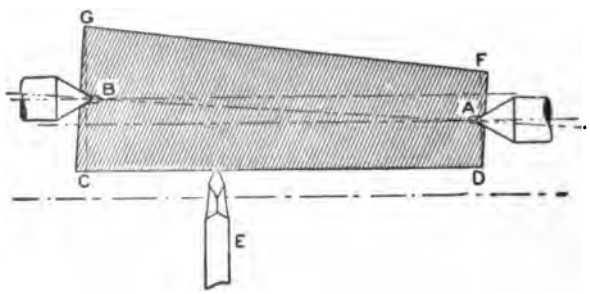


Fig. 137.

Turning. The first operation usually performed on a piece of work when placed in the lathe is facing or squaring up the ends. This must be done to get a uniform bearing for the centers. The finishing of all surfaces at or nearly at right angles to the axis of the work is classed as facing, and the side tool (Fig. 127) is usually employed. For roughing cuts the cutting face of the tool is placed at a slight angle to the work surface in order to remove the metal quickly; but for finishing cuts it is placed nearly flat against the work, so that a light thin chip may be taken.

Turning the cylindrical portions of the work is next done by the use of the diamond point or similar tool. Roughing cuts are taken to within about $\frac{1}{64}$ inch of the finished size, and a fine finishing cut reduces the work to the exact diameter. For roughing cuts, common calipers should be employed, while for finishing cuts, the micrometer caliper is most suitable. All measurements must be taken with the lathe at rest, as motion of the work renders close calipering impossible.

Turning a Taper. It frequently happens that a piece must be turned tapering; that is, one end is to have a greater diameter than the other. There are three ways of accomplishing this result: setting the dead center over, the use of the compound rest, and the use of the taper attachment. Setting the dead center over is the most common method. Provision is generally made for moving the dead center laterally towards the front or rear of the bed according to the taper required. With the dead center set-over, the tool will be at unequal distances from the live and dead centers, because its movement is parallel to the axis of the lathe. This is shown in Fig. 137. The piece to be turned is placed upon the centers A and B, and the dead center is moved from the axis a distance equal to the difference between the radii A D and B C. This leaves the side D C parallel to the center line of the lathe; hence the tool will be fed along this line. The objection to doing work by this method is that the lathe centers do not have full bearings at the ends of the work, and the center holes are likely to wear out of their true positions.

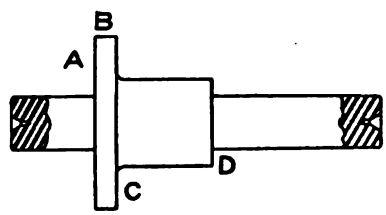


Fig. 138.

If the taper is to be turned on a piece held by a mandrel, or if the taper is to extend but a part of the total length of the work, the amount of set-over for the dead center must be calculated in the same manner as though the taper were to extend the whole length of the mandrel or work. In other words, the amount of set-over for the dead center is determined by the distance between the centers and the rate of taper.

For example: Suppose the mandrel in Fig. 138 to be 16 inches long, and the piece of work C D which is to be turned tapering, is 4 inches long; suppose also, that the diameter at D is to be $\frac{1}{4}$ inch smaller than at C. Then for one inch of length, the difference in diameters would be one-fourth of $\frac{1}{4}$ inch, or $\frac{1}{16}$ inch, and for a length of 16 inches it would be sixteen times $\frac{1}{16}$ inch, or 1 inch. Since the set-over is equal to the difference of the radii, the set-over for the 16 inches would be one-half of 1 inch, or $\frac{1}{2}$ inch.

This, then, would be the set-over for the work under consideration, and for any piece to be tapered at the rate of $\frac{1}{4}$ inch in 4 inches when held on a 16-inch mandrel.

EXAMPLES FOR PRACTICE.

1. A tapered bushing 3 inches long and of 4 and $4\frac{1}{4}$ inches outside diameters is driven on a 12-inch mandrel for turning. How much must the dead center be set out of line in order to do the work? *Ans.* 1 inch.

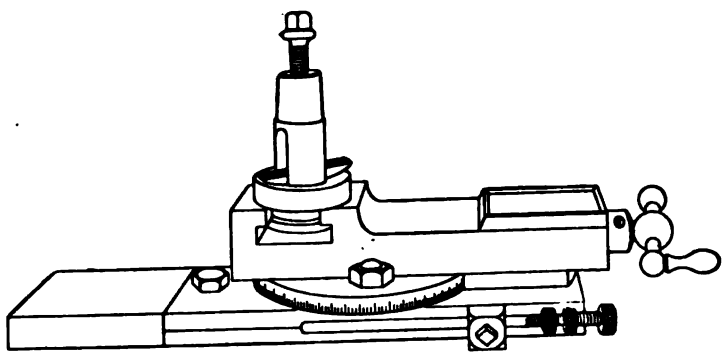


Fig. 139.

2. A connecting rod 6 feet long is to be turned tapering from the center to the neck back of the stub-ends. This distance is 26 inches. The diameter at the center is to be 3 inches, and at the neck $2\frac{1}{2}$ inches. How much offset must be given to the dead center? *Ans.* .692 + inches.

3. A shaft had a taper 2 feet long turned on one end. The large end of the taper was 4 inches in diameter, and the small end was 3 inches in diameter. The dead center was set over 1 inch. How long was the shaft? *Ans.* 4 feet.

The machinist generally sets over the dead center as accurately as possible and takes a roughing cut. The taper is then tested by a careful comparison of the diameters or by trying it in a tapered hole of the proper angle, and the center set more accurately. Setting over the dead center does not give accurate results, on account of the fact that the centers do not have a true

bearing at the ends of the work. The shorter the work, compared with the amount of set-over, the greater the inaccuracy.

In turning a taper with the compound rest, the work may be held in a chuck, on the faceplate, or between the centers. The compound rest, Fig. 139, is then set at such an angle that the direction of the motion of the tool will coincide with the required taper. Several methods are employed for this adjustment of the rest. The tool is then fed to the work by means of the feed handle attached to the compound rest.

The taper attachment, Fig. 140, is in the form of a guide which is bolted to the back of the lathe. It can be set at any desired angle with the axis of the lathe, the limit usually being a taper of about three inches per foot. The guide is graduated so

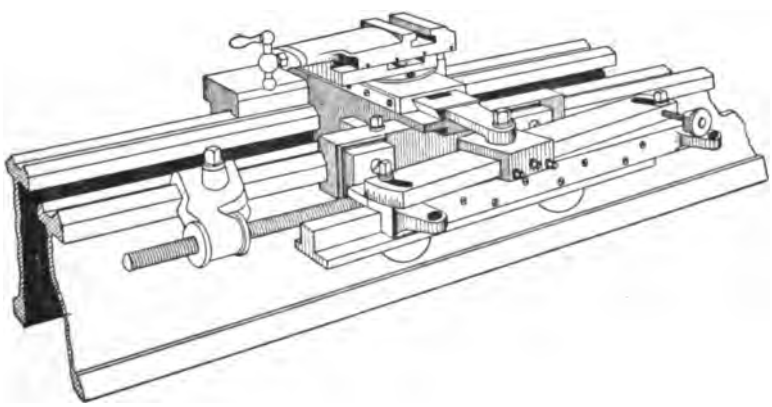


Fig. 140.

that calculations based on the length of the work are unnecessary. A slide moving with the guide is attached to the cross-feed of the carriage. The cross-feed is loosened, and, while the carriage is moved by the feeding mechanism, the tool is moved in or out according to the direction of the taper.

One of the most important points to be observed in turning tapers is to have the cutting point of the tool exactly level with the centers. If this is not done, the work will not be truly conical, and, furthermore, the rate of taper will vary with each succeeding cut.

In case an internal and an external taper are to be turned so as to form a fit, the internal taper should, if the character of the work will permit, be made first. After this has been done, the external taper should be turned and tested several times during the process. The external taper is first turned as accurately as possible, taking care that the piece be made a trifle too large. Draw a chalk line on the external taper, from one end to the other, press the tapers together, and give one of them a slight twist. On separating the tapers, the rubbing of the chalk will show where the work was in contact, and, by resetting the lathe and repeating the process, a very accurate fit can be obtained.

Shafting is usually turned $\frac{1}{16}$ inch less than the nominal diameter. For instance, instead of a shaft 2 inches in diameter, one of $1\frac{15}{16}$ inches in diameter is used. The reason is that iron of a nominal diameter of 2 inches, usually $\frac{1}{32}$ inch over size, can be used. Before turning a length of shafting, the rough bar should be carefully straightened. After the center holes have been drilled and the piece placed in the lathe, the work can be turned and the eccentric portions marked with chalk. When this has been done, the bar should be removed from the lathe and sprung back into true alignment. It is well to take two cuts for finishing shafting, one for the roughing cut and one very fine finishing cut. The tool for the latter part of the work should be kept flooded in oil, or a solution of sal soda. If the work is light, a tool-holder, carrying both the roughing and the finishing tools, should be used. This makes it possible to do the work in what practically amounts to the time of one cut.

As a length of shafting is likely to spring under the pressure of the tool, some method of preventing such action must be employed. A steady rest can be used. It is, however, inconvenient and must be frequently moved or it will stand too far, at times, from the tools. Furthermore, as the rough bar will neither be truly round nor concentric with the centers, it is necessary to turn "spots" for the center rest. This operation takes considerable time, owing to the fact that very light cuts must be taken in order to avoid springing the bar. The best method is to have a ring attached to the tool-holder; the internal diameter of this ring is that of the finished shaft. It is slipped over the tail-stock cen-

ter and follows the finishing tool. It must, of course, be rigidly fastened to the tool-holder. In this way the shaft is supported close to the tools; the ring also serves as a gauge to measure the diameter of the shaft. If, for any reason, the tools turn to a larger diameter than the inside of the ring, notice is immediately served upon the workmen to that effect by the binding in the ring.

Eccentric Turning. Up to this point, the work described for the lathe has been of the kind in which the turning is done on work concentric with the lathe centers. There are other classes of work that are offset and for which special provisions must be

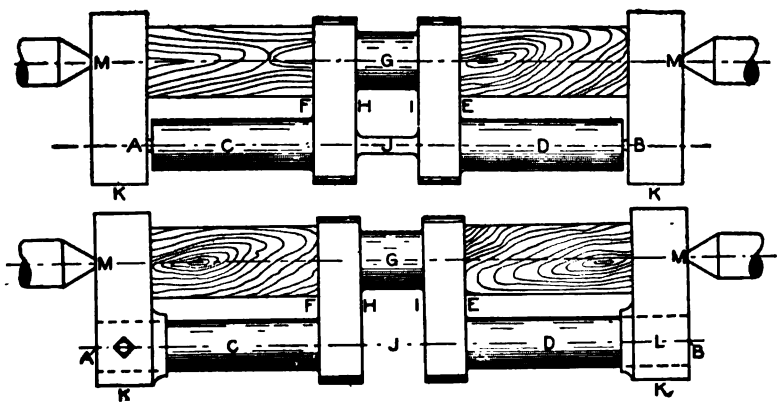


Fig. 141.

made. Of course the surface being turned must always be concentric with the spindle.

The turning of crank shafts presents conditions where there are two cylindrical portions, each parallel to and concentric with the lathe axis while being turned, but eccentric with regard to each other. In Fig. 141 such a shaft is shown. This may be either a casting or a forging. If cast, it is common to have a small web, shown at J, in the original casting to take the thrust of the centers while turning the shaft portions C and D. After centering the work at A and B, the shaft is placed in the lathe, and the ends A and B squared up, and surfaces C and D roughed out. If a forging is being worked, it will be necessary to insert a wooden block at the point J. Two lugs or ears K are provided

to fit tightly on the rough turned shaft, the distance from the center of the hole L to the center M being equal to the throw of the crank. These lugs are attached to the ends of the shaft, so that a line joining the centers M will pass through the axis of the crank pin G. Blocks are now placed between the lugs and the crank pin, the web or block at J removed, and the pin turned on the new centers M M. The crank pin G is roughed and finished, and the shoulders H and I faced, at this time. Removing the lugs and blocks, the surfaces C and D are finished and the shoulders E and F faced on the centers A and B. If the shaft is of any considerable weight, it should be counter-balanced by attaching weights to the faceplate. The reason for not finishing the shaft at the first operation, is that removing the scale from a casting or the outer skin from a forging releases internal stresses which are likely to change the shape of the piece. As a general rule, a piece of work should be completely roughed out, if possible, before any finishing cuts are taken. The change in shape, due to the removal of the outer portion of the stock, does not all take place immediately; and, if very accurate results are desired, it is good practice to allow the roughed work to stand some time before finishing.

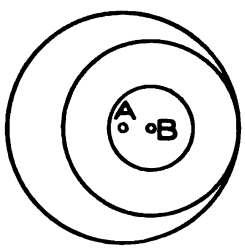


Fig. 142.

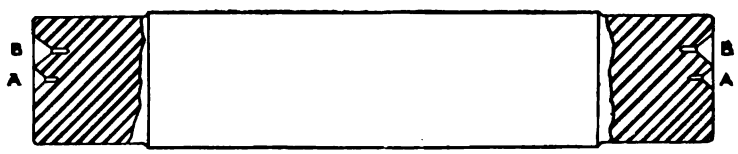
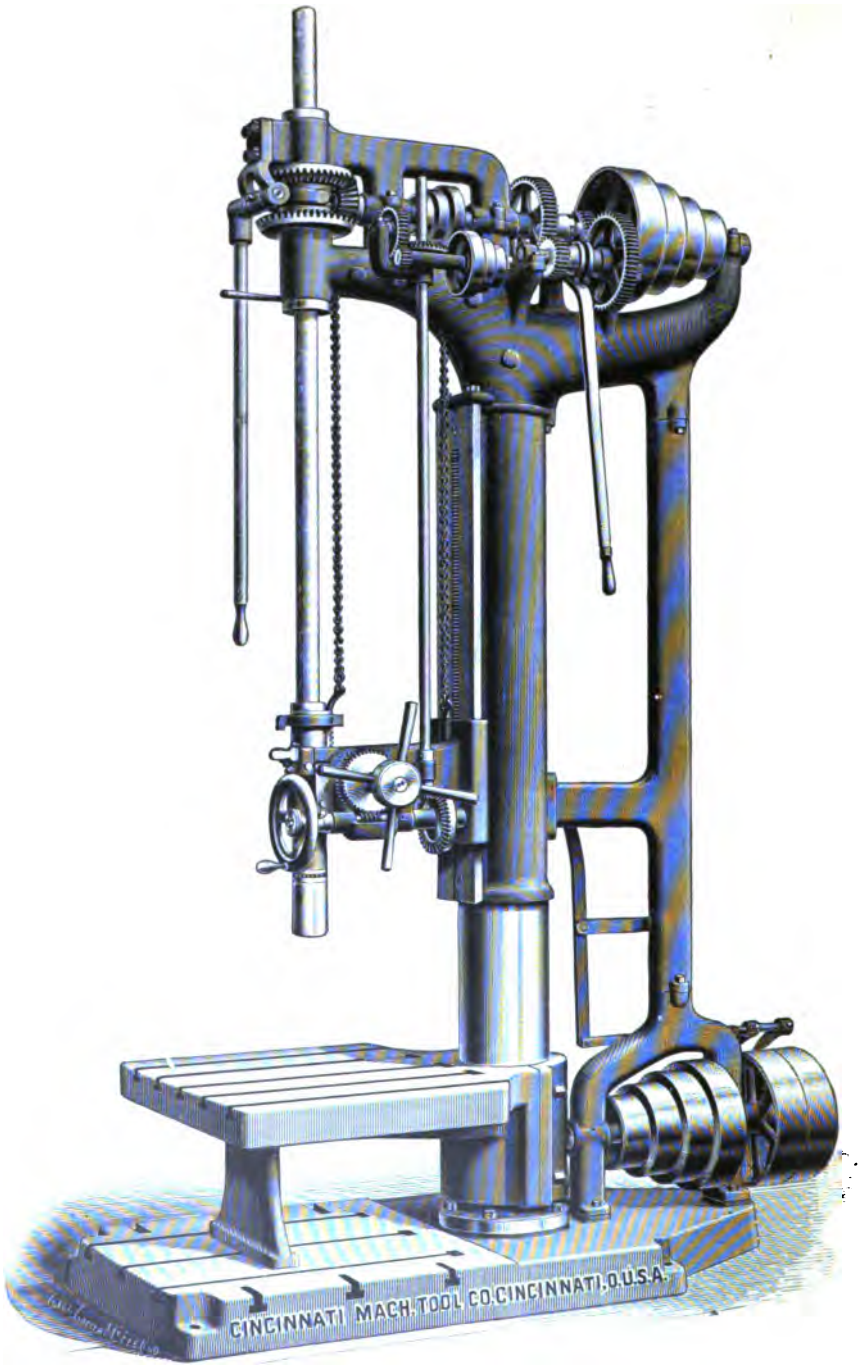


Fig. 143.

Turning an Eccentric. As far as its use in mechanism is concerned, an eccentric is the equivalent of a small crank, but it requires very different treatment in the lathe. In the first place, it is not usually made solid with the shaft, but is a comparatively thin casting or forging which is fastened to the shaft by set screws or keys. The general shape is shown in Fig. 142, and



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consists of the eccentric proper and a boss to reinforce the shaft hole; this boss usually being on but one side of the casting. In Fig. 142, A is the center of the eccentric and B the center of the shaft.

Small eccentrics, especially those having a throw less than the diameter of the shaft, may be finished in the following manner: The casting is grasped in an independent chuck, one having four jaws being preferred, with the boss or hub running as nearly true

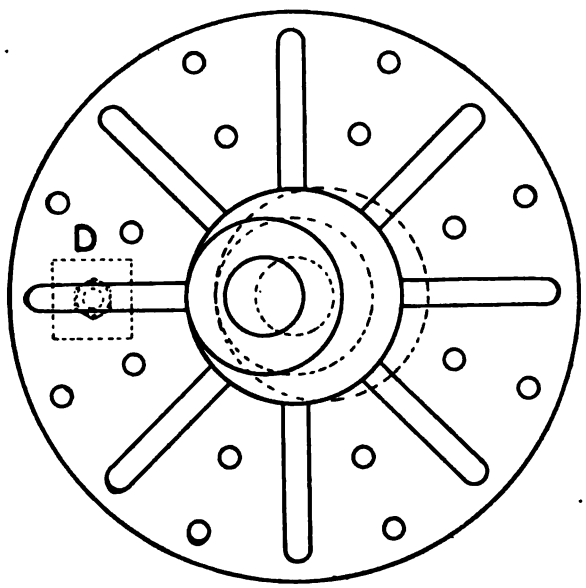


Fig. 144.

as possible. The projecting face of the eccentric, together with the outside and face of the hub, may be machined, and the hole can be trued up with a boring tool or by the use of the chuck drill and reamer. In either case, it is advisable to obtain the exact diameter by using a finishing reamer. The eccentric may now be placed on a special mandrel, shown in Fig. 143, which has an extra set of center holes. A line connecting these holes is parallel to the axis of the mandrel, and at a distance from it equal to one-half the throw of the eccentric. It is obvious that this mandrel is the equivalent of the shaft and lugs used in turning solid crank

pins. On these extra centers the outside of the eccentric may be turned, and, on the regular centers, the back or plain face can also be finished. This completes the eccentric as far as the lathe is concerned.

Large and heavy eccentrics are preferably finished on a faceplate. The plain side or back having been previously machined, the eccentric is clamped to the faceplate with the hub running true, shown dotted in Fig. 144, and the face of the hub and the

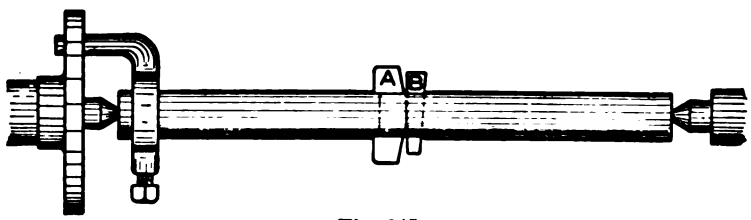


Fig. 145.

hole are finished as in the case of the small eccentric held in the chuck. The diameter of the hole being comparatively large, a reamer is not generally used. The eccentric is now moved on the faceplate a distance equal to one-half the throw of the eccentric, bringing the outer surface concentric with the lathe axis, as shown by the full lines, and the clamps placed so as to allow the outside to be turned. It is often necessary to balance the work by counterweights, in order to have the lathe run steadily. This is shown at D in Fig. 144.

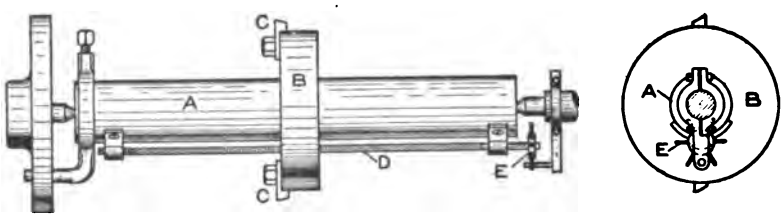


Fig. 146.

Boring. The boring of holes sometimes calls for a length and strength of tool that cannot be readily attained with the ordinary boring tool. A great deal of such boring is done with double-headed tools. These tools are held in bars and cut at each end. An ordinary form of such a tool is shown in Fig. 145.

The tool A is turned and fitted so that when placed in the bar it is central with the centers of the latter. It is held in position by the key B. It cuts at each end. Such a tool may be made to do very rapid work. It is extensively used for boring car wheels, and in other places where a piece of work must be duplicated a great number of times.

Tools of this character are used for finishing. After the cut has been started the tool should not be stopped until the cut has been completed. If it is stopped there will be a ledge in the bore at that point. The reason for this is due to the springing of the metal and the contraction due to cooling while at rest. The tools used for finishing usually have a broad surface. Those used for

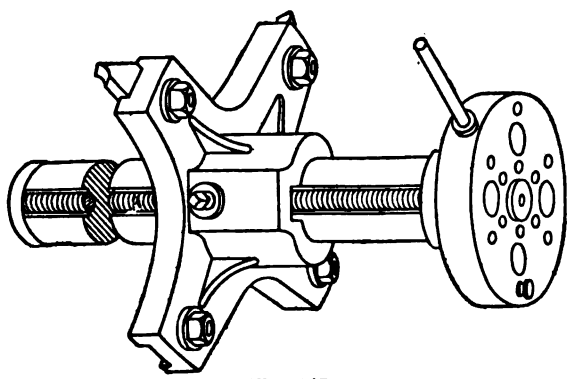


Fig. 147.

the roughing-cut are narrower; they wear more rapidly than the finishing tools and are usually adjustable. A roughing tool may be held by a wedge as shown at B. Such a tool is placed in position and the wedge tightened just enough to hold it. The adjustment of the tool is then obtained by tapping it with the hammer. It is then held firmly by driving the wedge. An excellent example of this style of work is found in the boring of engine cylinders. Special machines are used for such work. The greater portion of it, however, is done in an ordinary lathe with a boring bar, as shown in Fig. 146. It consists of a heavy bar A, upon which there is a stiff traveling head B. The latter carries the tool C, which may or may not be capable of a transverse adjustment. The head moves longitudinally over the bar and is held,

adjusted and fed by the screw D. At one end of the screw there is a star wheel, E, by which it is turned. As the bar revolves, one arm strikes against a stop at each revolution. This turns the screw by an amount proportional to the number of arms in the star. For example, if there are six arms in the star, the latter will be turned one-sixth of a revolution for each revolution of the boring bar. As the screw turns, it moves the head along the bar by an amount proportional to the pitch of its thread and the rays or arms in the star. This forms the feed of the tool. For example, if a star has four arms, and is keyed to a screw of eight threads to the inch, then for each revolution of the bar the head will be advanced $\frac{1}{32}$ of an inch. Another form of boring bar is shown in Fig. 147.

Boring bars with fixed tools are also used. In such cases the work is caused to travel beneath the bar as it is turned. A case of this kind occurs in the boring out of brasses for railroad cars.

It may be stated that, in general, all metal work should be finished in the position which it is eventually to occupy. This is

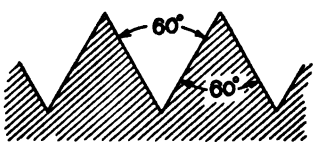


Fig. 148.

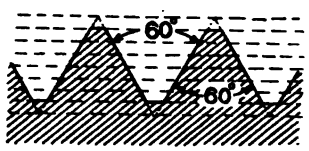


Fig. 149.

due to its tendency to spring out of shape under the influence of its own weight. For small articles this influence is inappreciable. For large pieces it is sometimes quite apparent.

SCREW CUTTING.

The tools used for cutting threads are called *screw-cutting tools*. These tools are used in the lathe in the same manner as the diamond point and round-nosed tools. The cutting edge of the tool must be of the same shape as the space between the finished threads.

There are five types of screw threads commonly used in this country: the V thread, shown in Fig. 148, has the form of an

equilateral triangle with an angle of 60°. It is sharp at the top and bottom. This thread is difficult to cut because of the trouble experienced in keeping the point of the tool sharp.

A modified form of V thread, known as the Sellers, the Franklin Institute, or the United States Standard, is shown in Fig. 149. This thread has an angle of 60°, with the top and bottom flattened for one-eighth of its depth. It is stronger than the V-shaped thread, and permits greater accuracy in cutting.

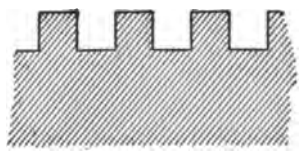


Fig. 150.

Another form in common use is the square thread. This is shown in Fig. 150. The thread and space are of the same width. These screws are used when heavy work is done, such as in jack-screws and presses.

The Whitworth thread is similar to the United States Standard; the slight differences are as follows: the sides form an angle of 55° instead of 60°, and the top and bottom are rounded instead of flat.

The fifth type, the Acme thread, is similar to the square form. The difference is that the sides incline $14\frac{1}{2}°$ from those of the square thread. This form of thread is much used for lathe

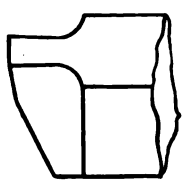
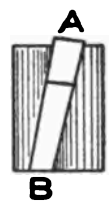


Fig. 151.



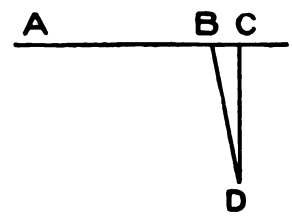


Fig. 152.

lead screws and for giving motion to sliding parts of fine instruments, because the thread is much stronger than the square form, and the lost motion can be taken up by simply closing the nut halves nearer together.

The tool used for cutting square threads is shown in Fig. 151. It is of the proper thickness at the cutting edge, but is somewhat narrower back of this point. The sides of the tool are inclined to the body, as shown at A B, Fig. 151; the amount of

this inclination varies with the pitch of the thread and the diameter of the piece on which the thread is to be cut. To find the inclination, draw an indefinite straight line A C and at right angles to it draw C D. Make the length of C D equal to the circumference of the thread to be cut, measured at the root of the thread. On A C lay off from C a distance (B C) equal to the pitch; then draw B D. This line will represent the angle of the side of the thread. The angle of the side of the cutting tool must be a little greater for clearance.

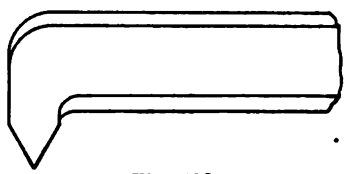


Fig 153.

For cutting *inside* threads, the shape of the cutting edge of the tool should be the same as for cutting an outside thread, but the tool must be made so that the cutting edge alone touches the work. This is accomplished by bending the tool as shown in Fig. 153 and giving it considerable clearance.

Standard Screw Threads. When screw threads are to be cut, the pitch used depends upon the outside diameter of the bar. A standard has been adopted by all of the leading technical societies of the United States, and is known as the United States Standard. The table (see opposite page) gives the outside diameter of the screw from ¼ inch to 6 inches in diameter, with the number of threads per inch to be cut.

In placing the tool for any form of thread, the point of the tool must be exactly level with the center, and a line at right angles to the axis of the lathe must bisect the angle of the tool point. In order that these conditions may be fulfilled, a thread or center gauge, Fig. 154, is used. In this tool, the angles, A, B, and C are made exactly 60°. The two opposite sides are parallel. The angle A at the end is used for grinding the tool. The sides of the latter are made to touch all along the edge. For setting the tool, the upper parallel side is held against the face of the work in a

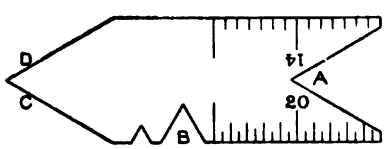


Fig. 154.

horizontal position. The tool is then set so that its sides touch along the edges of the notch B. The angle C is used to gauge the thread after it is cut.

UNITED STATES STANDARD SCREW THREADS.

Diameter of Screw in Inches.	Number of Threads per Inch.	Diameter of Screw.	Number of Threads per Inch.
1/4	20	2	4½
5/16	18	2¼	4½
3/8	16	2½	4
7/16	14	2¾	4
1/2	13	3	3½
9/16	12	3¼	3½
5/8	11	3½	3½
3/4	10	3¾	3
7/8	9	4	3
1	8	4¼	2½
1⅛	7	4½	2½
1¼	7	4¾	2½
1⅜	6	5	2½
1½	6	5¼	2½
1⅝	5½	5½	3½
1¾	5	5¾	2½
1⅞	5	6	2¼

The measurement of fine threads is a difficult matter where an ordinary rule is used and the threads between the inch marks are counted. For this purpose a pitch gauge, Fig. 155, is used. The gauges are short screw sections on thin sheets of metal. To ascertain the pitch of any thread, set the gauges over it successively until one is found that exactly fits. The figures stamped thereon will give the number of threads per inch.

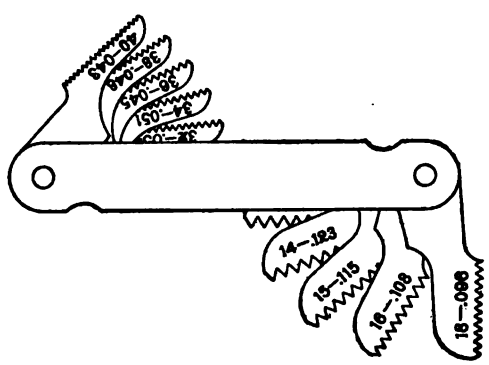


Fig. 155.

The cutting of a thread demands that there shall be a certain definite ratio of motion between the rotation of the work and the

travel of the carriage. When a right-handed screw is to be cut, the carriage travels from right to left. For example, if a screw having a pitch of ¼ inch, or with four threads to the inch, as it is usually expressed, is to be cut, the spindle must make four revolutions while the carriage is moving one inch along the bed. If the screw is to have eight threads to the inch, the spindle must make eight revolutions to each inch of motion of the carriage or tool; if six threads, then six revolutions to the inch of motion, etc.

If, then, the lead screw is cut with four threads to the inch, it is evident that the speed of rotation of the spindle and of the screw must be the same, in order to cut a screw of four threads to the inch. For each revolution of the lead screw, the carriage moves the distance of the pitch of the same or ¼ inch. Hence, the gears, J and L, Fig. 91, must have the same number of teeth. When a screw of eight threads per inch is to be cut, the spindle must make twice as many revolutions as the lead screw. Then, for each revolution of the spindle, the lead screw makes half a revolution and thus moves the carriage ⅛ inch. In this case, the screw gear L must have twice as many teeth as the spindle gear J. For six threads, the ratio of revolutions between spindle and screw is 1½ to 1. This requires 1½ times as many teeth in the screw gear L as in the spindle gear J.

The rule for finding the gears to be used on the spindle and lead screw is: Multiply the number of threads on the lead screw and the number of threads to be cut by the *same* number; the products will equal the numbers of teeth on the gears to be used.

Suppose the lead screw has four threads per inch, and ten threads per inch are to be cut. Multiply both numbers by any convenient number, such as 3. Then the gears should have 12 teeth and 30 teeth.

Let a = the number of threads per inch on the lead screw,
b = the number of threads per inch to be cut,
c = a convenient number,
$a\,c$ = the number of teeth of gear on spindle,
$b\,c$ = the number of teeth of gear on lead screw.

If the gears thus found are not at hand, multiply by some other number. Thus, suppose gears of 30 and 12 teeth were not

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available, multiply 4 and 10 by 4 or by 5 or any other number that would give the number of teeth on the gears at hand.

Another way to find the gears is to remember that the number of threads to be cut is to the number on the lead screw as the number of teeth on the screw gear is to the number of teeth on the spindle gear.

EXAMPLES FOR PRACTICE.

(1) The lead screw has a pitch of $\frac{1}{4}$ inch. What is the ratio of gears to be used to cut a screw with 9 threads to the inch? If one gear has 24 teeth, how many should the other have? Ans. $\begin{cases} 1 : 2\frac{2}{3} \\ 54 \text{ teeth.} \end{cases}$

(2) The lead screw has a pitch of $\frac{1}{4}$ inch. What is the ratio of gears to be used to cut a screw with 16 threads to the inch? Ans. 1 : 4.

(3) The lead screw has a pitch of $\frac{1}{8}$ inch. What is the ratio of gears to be used to cut a screw with 12 threads to the inch? Ans. 1 : 4.

In these cases the actual number of teeth in the gears to be used is obtained by multiplying the ratio by some common multiple. Thus in example 1, multiplying by 10 gives 40 teeth for the spindle gear and 90 for the screw gear. In example 2, multiplying by 20 gives 20 teeth for the spindle and 80 for the screw gear; and the same result is obtained by using the same multiple for example 3.

Every screw-cutting lathe is provided with a set of gears from which selections can be made. In order to facilitate the choice of the gears to be used, a *gear table* is usually cast in raised letters and screwed to the front piece of the headstock. This table shows the gears to be used for cutting such threads as may be enumerated on the table.

It is sometimes necessary to cut a screw for which there are no gears to make a direct connection. This necessitates the compounding of the gears on the intermediate spindle to replace the single gear. This is done as shown in Fig 156, in which A represents the spindle and B the screw. Suppose, with a lead

screw having three threads to the inch, it is desired to cut a screw having thirteen. This makes the ratio of teeth on the spindle gear to those on the screw as 3 to 13. The work can be done with spindle gears having 15, 30, or 45 teeth with screw gears having 65, 130, and 195 teeth respectively. If it is found that there are no gears having 15, 45, 130, or 195 teeth on hand, compounding must be resorted to. To determine the gears to be

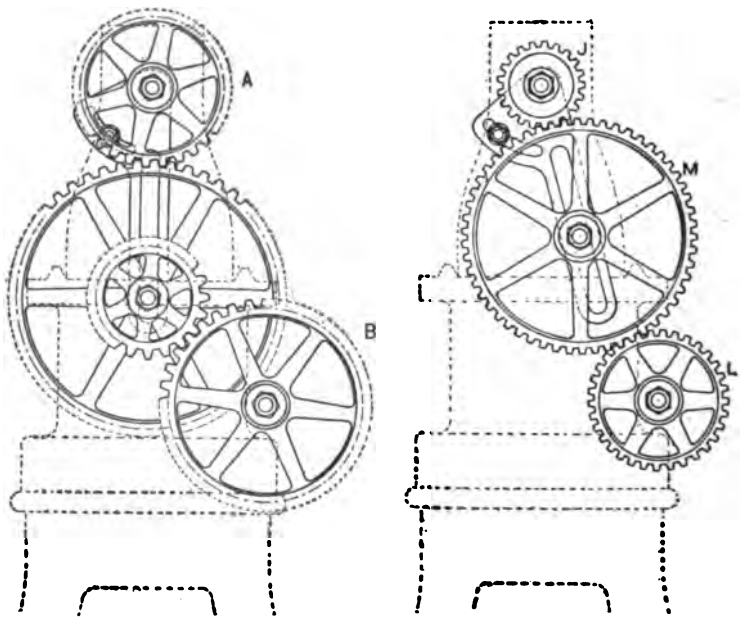


Fig. 156.

used it must be remembered that *the product of the numbers of teeth in the driving gears must be to the product of the numbers of teeth of the driven gears, as the number of threads per inch on the lead screw is to the number to be cut.* In this case it is as 3 to 13. Multiply each of these figures by any convenient multiple. In the example in hand, let the multiple be 200. Then

$$\frac{3 \times 200}{13 \times 200} = \frac{3 \times 2 \times 2 \times 2 \times 5 \times 5}{13 \times 2 \times 2 \times 2 \times 5 \times 5}.$$

Select from the factors thus obtained two sets, each of which, when multiplied together, will give products equal to the number of teeth that are on hand.

Thus in the numerator we may take $3 \times 2 \times 5$ and $2 \times 2 \times 5$, giving 30 and 20 as gears that are to be used as the spindle and intermediate drivers respectively.

For the denominator take 13×5 and $2 \times 2 \times 5$ or 65 and 20, for the driven gears of the intermediate stud and the screw respectively. Placing these in position as in Fig. 157, we have,

Gear A with 30 teeth.
Gear C with 65 teeth.
Gear D with 20 teeth.
Gear B with 40 teeth.

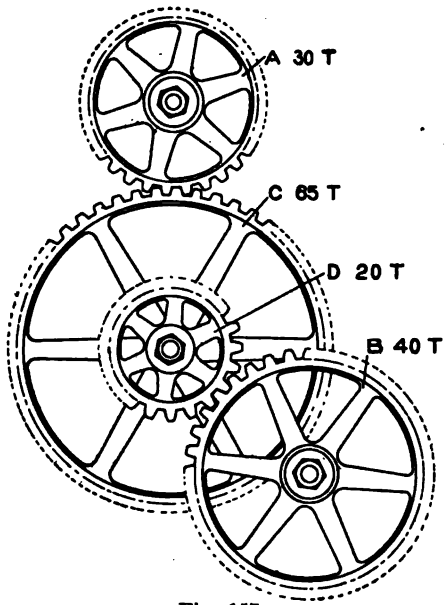


Fig. 157.

It is desired to cut a screw with 11 threads to the inch on a lathe having a lead screw with a pitch of $\frac{1}{4}$ inch. The gears available have 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, and 100 teeth respectively. What ones are to be used and where?

Ans.

Spindle	40 teeth
Intermediate driven	55 teeth
Intermediate driver	50 teeth
Screw	100 teeth.

Many screw-cutting lathes are not made with an extension of the spindle to receive the first gear, but a short shaft or stud projects from the headstock for this purpose. This stud is geared to the spindle, and the ratio of this gearing must be considered when calculating the gears for screw-cutting. For example, suppose we wish to cut twelve threads per inch in a lathe having a lead screw with eight threads per inch and a ratio of two to one between the spindle and the stud. In other words, the stud runs half as fast as the spindle. As we have seen in the previous examples, the ratio between the spindle and the lead screw must be 12 to 8.

The first gear is not attached to the spindle, but to the stud, which makes six revolutions to twelve of the spindle. Therefore, the ratio between the stud and the lead screw, where the gears are actually applied, must be 6 to 8. Multiplying by 6 will give 36 and 48 as the number of teeth in two gears which may be used.

In general, the data that must be given to calculate the change gears for screw-cutting are the number of threads per inch to be cut on the work, the number of threads per inch on the lead screw, and the speed ratio between the spindle and the stud, if a stud is used.

The following examples may be taken as applying to either right- or left-hand threads. The change of direction in the travel of the carriage is obtained by introducing an extra gear into the train, thus reversing the rotation of the lead screw.

The following description of the method of cutting a "V" thread will suffice to illustrate the cutting of any form, with the slight changes which are necessary in the other forms due to the shape of the tool employed.

To cut an ordinary V thread, a V-pointed tool having an angle of 60°, and set so that a line at right angles to the lathe axis bisects the tool angle, and also set exactly at the height of the center, is caused to move at a constant rate parallel to the work surface, while the work is being uniformly rotated.

The relation between the rotary motion of the work and the lateral movement of the tool, determines the pitch of the thread being cut, and the mechanism connecting the work and the tool must be of a positive character; thus eliminating transmission by belts and other frictional devices.

Owing to the lost motion or "back lash" in the mechanism connecting the tool and the work, the tool cannot be returned to the starting point for a new and deeper cut by simply reversing the lathe. The tool must be withdrawn, the lathe reversed, the tool returned to the starting point, and then advanced for the new cut. To place the tool for the new cut with accuracy, a stop or graduated device is provided.

If removed from the lathe for testing, care should be taken in replacing the work to get the tail of the dog in the same slot

in the face place that was used to cut the original thread; this can be done by marking or otherwise indicating it.

Chasing. The ordinary methods of cutting screws have already been described. Where great accuracy is not necessary, the threads may be chased by hand. A chaser, or chasing tool, differs from the ordinary thread-cutting tool, in that it has a number of cutting points instead of but one. When a chaser is operated by a power feed, it is customary to have a shaft revolving at the same rate or at an even multiple of the rate of the lathe spindle. This shaft carries a master thread into which a section of a nut drops. The handle connected with the nut carries the chasing tool. When the nut is in contact, the tool is cutting. At the end of the cut, the tool is lifted out, and with it the nut disengages with the thread.

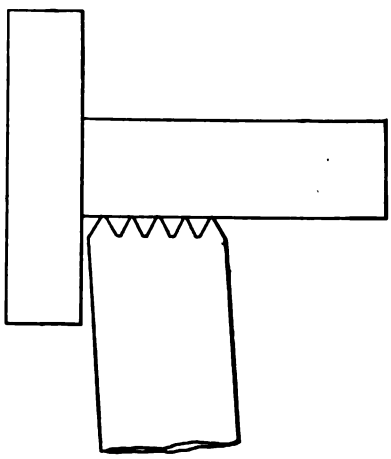


Fig. 158.

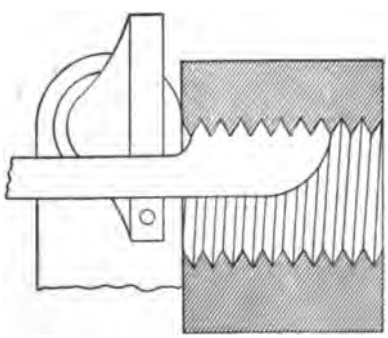


Fig. 159.

Hand-chasing requires a great deal of skill in order that a good piece of work may be done. The chasing tool has a number of points as shown in Fig. 158. The work must be run rapidly in the lathe. The tool is held in both hands, and is supported on a rest similar to that shown for the wood-turning tools in Fig. 86. The first left-hand tooth of the chaser is brought lightly against the right-hand edge of the work. The handle is given a quick twist from left to right throwing the teeth in the opposite direction. It is well after the first twist, to stop the lathe and examine the

work. If the operation has been properly performed, the second tooth will be found to have entered the groove made by the first. A short length of thread will have been cut, the pitch being the same as that of the chaser. If this is correct, the lathe may again be started and the chaser applied as before. On the second trial the thread may be run to its full length. The finishing of the thread is done by merely repeating the operation. A fine cut is taken with each application of the chaser for the whole length of the thread until the full depth has been cut. In doing this work, the rear or right-hand side of the chaser should be pressed more firmly against the piece being cut than the front, because the threads with which that portion of the tool is engaged are more deeply cut than at the front. In addition to cutting, these teeth also guide the front. The reason for running the lathe at a high rate of speed, is that the movement of the chases is less likely to be checked or thrown aside by seams or inequalities in the density of the metal than it would be if the lathe were to run slowly. Inside threading may be done by means of the inside chaser shown in Fig. 159.

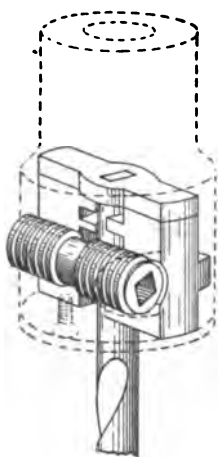


Fig. 160.

Drilling in the Lathe. The lathe can also be used for drilling. When such work is to be done, the drill may be held in the spindle and the work forced up against it by the screw of the tail stock; or the work may be revolved and the drill forced in by the tail-stock screw. When the first method is followed the drill may be put into a socket prepared for it in the spindle of the lathe, or the drill may be held by a drill chuck as shown in Fig. 160. This chuck may be used in the tail-stock to hold twist drills, or to hold flat drills which are forged from round stock. Flat drills made from flat stock are centered at the rear end and held against, and fed forward by, the dead center. In this case, a slotted rest held in the tool post prevents the drill from turning (see Fig. 65) and aids in starting the drill true.

When the drill is held in the head stock, the work may be

fastened to the carriage and fed against the drill, or it may be held by means of a suitable device held in the tail stock. For this purpose the drill pad, shown in Fig. 161, may be used, and especially if the work be flat. The V center, shown in Fig. 162, is

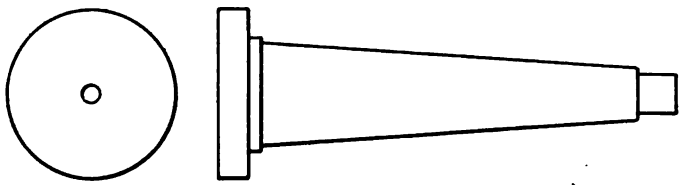


Fig. 161.

used when it is desired to drill through the axis of a piece of round stock. The shape of the groove prevents the work from turning and the angle being always in the axis of the lathe determines accurately the location of the hole.

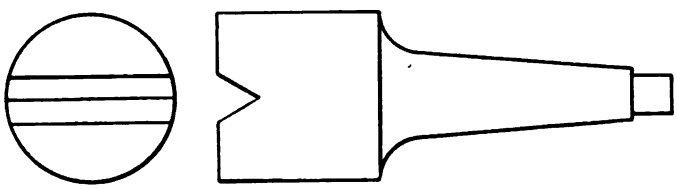


Fig. 162.

THE DRILL PRESS.

This tool is made in a great variety of forms, according to the class of work it is intended to perform. The form illustrated in Fig. 163 is one of the standard makes. The mechanism is very simple and will be briefly explained.

The frame consists of a strong column A, securely bolted to a heavy base-plate B. Power is delivered to the machine by means of a belt running over the cone pulley C. The shaft upon which this cone pulley turns, runs through the casing D, where, by means of miter gearing, it drives the vertical drill spindle E. It will be seen that there are four steps on the cone pulley C, thus affording a means for securing as many rates of revolution of the drill spindle. This, however, is not sufficient to meet all the

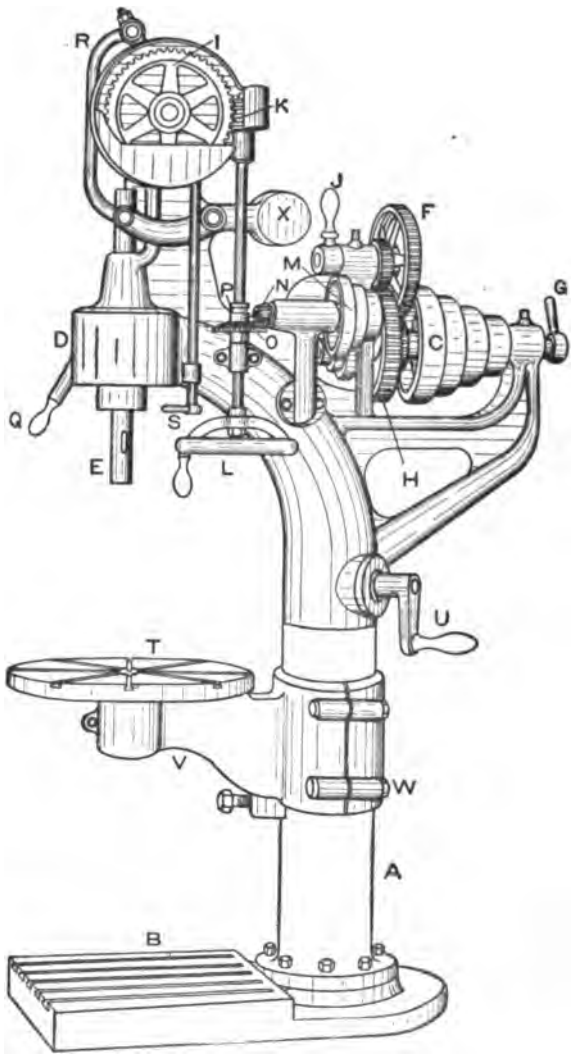


Fig. 163.

requirements of the work that can be done with the tool. In order to increase the range of available speeds, a *back gear* is used. This is shown at F. It consists of a gear and pinion keyed to the same shaft. The cone pulley C is loose on the horizontal shaft, but may be fastened to it by a clutch operated by the button G. The inner end of the cone pulley carries a pinion that meshes with the gear F, while the pinion attached to F meshes with the gear H that is keyed to the horizontal shaft. The gear F and its pinion run loosely on a journal that is, in turn, attached to an eccentric bearing. By turning the handle J, which is attached to the eccentric bearing, the gears may be thrown in or out of mesh. While the gears are in mesh, the power passes from the cone pulley to the pinion attached to it, to the gear F, to its pinion, and thence to the gear H, and thus turns the shaft. Under these circumstances the shaft is turning much slower than the cone pulley.

The feed, or downward motion of the drill spindle may be accomplished by hand or by power. At the upper end of the drill spindle a rack is cut, into which a pinion on the same shaft as the worm wheel I meshes. It is evident that, as this wheel revolves, the spindle will be raised or lowered.

The weight of the spindle is counterbalanced by the weight X. The worm wheel I is turned by the worm K, which is rotated by the hand wheel L. This serves for a hand feed. For a power feed, a belt is made to drive the cone wheel M. This turns the bevel pinion N, meshing with the bevel gear O, that is loose on the feed shaft. It is fastened to the latter by means of a small clutch P. A quick return of the spindle is accomplished by means of the handle Q. This is attached to the spindle by means of a yoke R. When the quick return is to be used, the worm K is thrown out of mesh with its wheel by turning the handle S.

The table T may be raised or lowered by means of the handle U; this drives a screw in the standard running in a nut fastened to the bracket V. When the table has been adjusted, it may be fastened by the nuts and bolts W clamping it to the standard A. When large work is to be drilled, the table may be swung out of the way and the work bolted to the base plate B.

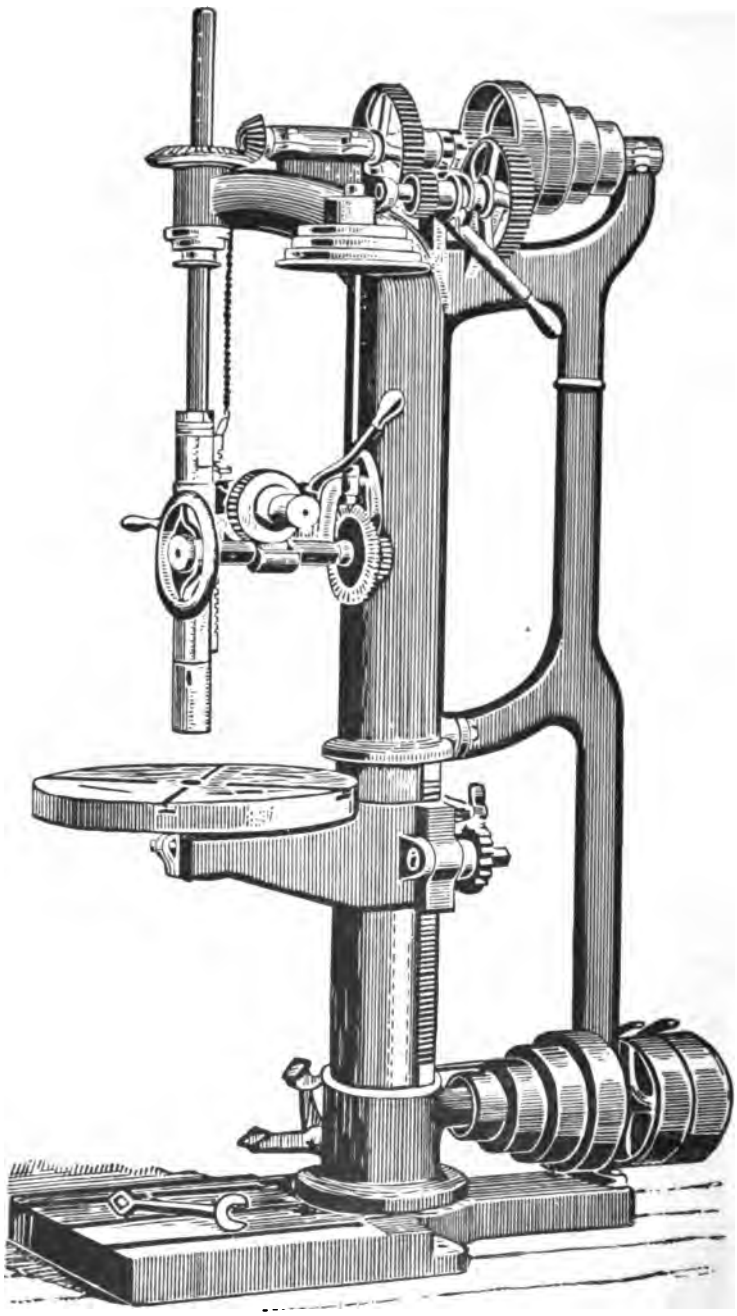


Fig. 164.

While the drill press just described may be taken as representing good practice in the smaller sizes, a different form of construction is often employed in larger tools. A drill press of this class is shown in Fig. 164. Drilling machinery is made both horizontal and vertical. A typical form of the horizontal variety is shown in Fig. 165. These tools are usually of heavier construction and for a larger class of work than the ordinary vertical drill.

Drilling machinery, both horizontal and vertical, is sometimes provided with more than one spindle. In small vertical drills of this description, the spindles are fixed in their relative

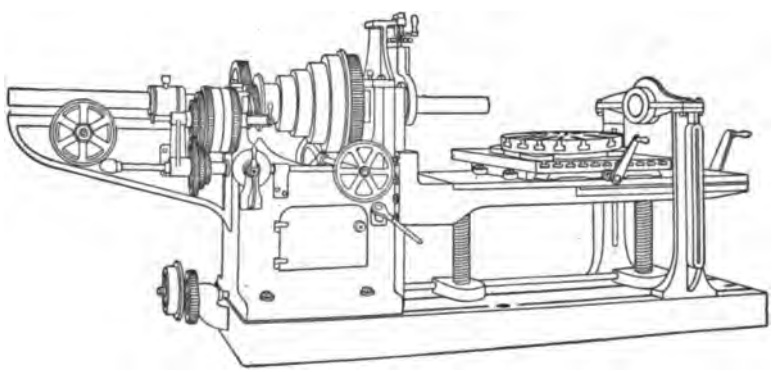


Fig. 165.

positions and are not intended to be operated simultaneously; the work is passed from one spindle to another. The true multi-spindle drill is for the purpose of drilling several holes at one time and in any relative position within the limits of adjustment of the machine. Such a drill is shown in Fig. 166.

The Radial Drill. Another form of drill, known as the radial, is being extensively used. It is shown in Fig. 167.

The drill spindle is carried on the arm A. It is so arranged that it can be set and run at any position on this arm. At the same time, the arm may be swung around and clamped in any vertical or horizontal position about the upright B. These drills are usually employed on heavy work, where a number of holes are to be drilled.

In the case of the drill shown in Fig. 163, the work is

ordinarily light, and can be readily shifted so that the position of the holes can be brought beneath the drill. In heavy work, such as engine cylinders, however, this cannot be done. It is, therefore, necessary to be able to shift the drill and place it in a position to do the work. The radial drill affords the means of doing

Fig. 166.

this. When the vertical spindle carrying the drill can be rotated in the vertical plane, holes can be drilled, not only in any position, but also at any angle. Such a drill is called a Universal Radial.

The position of the holes is usually laid out for the guidance of the man at the drill. The work is best done as shown in Fig. 168. The center punch mark, indicated by A, shows the

location of the center of the hole. The circle upon which the prick punch marks BBBB are placed, gives the location of the circumference of the hole. To drill the hole, place the point of the drill in the center punch mark A, and drill into the metal until the center punch mark has been slightly enlarged, as shown by the circle C, Fig. 168. Then raise the drill and examine the work. If the countersink or hole, whose circumference is indi-

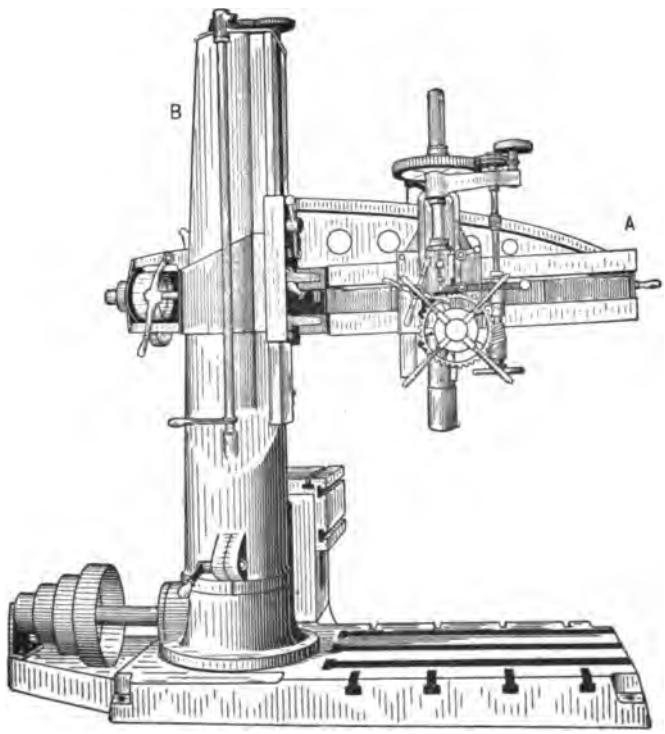


Fig. 167.

cated by the circle C, is exactly concentric with the outer circle BBBB, then the drill may be put down and the hole drilled.

Owing, however, to various causes, it is not often that the circle will be concentric. This may be due to an uneven grinding of the drill, a distortion of the metal by the center punch, or an eccentric motion of the drill point, due to a lack of truth in the running of the spindle.

When the countersink is not concentric, the drill must be drawn back to the central position. The method employed is shown in Fig. 169. The round-nosed chisel is used to cut a groove, E, down the side of the countersink, on the side that is farthest from the circle BBBB. The depth of this groove depends upon the amount of eccentricity of the countersink and the depth to which it has been drilled. The drill is then run down again and the groove drilled out. The action of this groove is as follows: as the drill turns, one cutting edge is supported, and is working into the face C, Fig. 170. At the same time the cutting edge is opposite the groove E. The drill, therefore, springs into

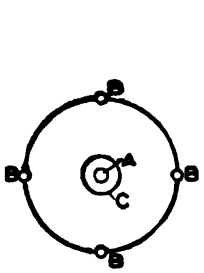


Fig. 168.

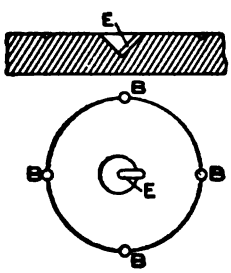


Fig. 169.

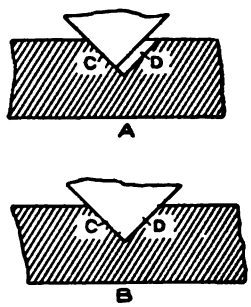


Fig. 170.

the groove, as shown. The lip then catches on the edge of the groove and cuts it away, making the hole elliptical, and shifting the center of the drill towards its proper position. As the drill sinks deeper both lips are in contact with the faces C and D, and it has no further tendency to shift.

When the groove has been drilled out, the drill must be again raised, to ascertain whether or not the countersink is concentric with the outer circle BBBB. If not, another groove must be cut, and the process repeated. If it is, the hole may be drilled. The prick punch marks BBBB are put on the outer circle to indicate its position in case of the obliteration of the line itself.

A twist drill will usually clear its hole of chips. For deep holes this may not occur. It is then necessary to withdraw the drill and clean out the hole. This can be done by a piece of wire bent at the end; also by using a "blowpipe" made of a small tube, and bent to enter the hole, so that the chips will not blow

up into the operator's face. Cast iron is more likely to need cleaning than wrought iron or steel. Where flat drills are used, it is always necessary to clean the holes at frequent intervals, as they have no tendency to raise the chips and clear the holes.

A matter to receive due consideration is that the work must be held rigidly on the table while being drilled. This may be done in two ways. If the holes are to be drilled with great accuracy, the work must be clamped to the table. This is often done by means of straps, as shown in Fig. 171. In this figure, a gland A is shown clamped to the table by the straps BB. One end of the strap rests upon the flange of the gland, and the other upon any convenient piece of metal C, of the proper thickness. The bolt D is put up through a hole in the table as close to the

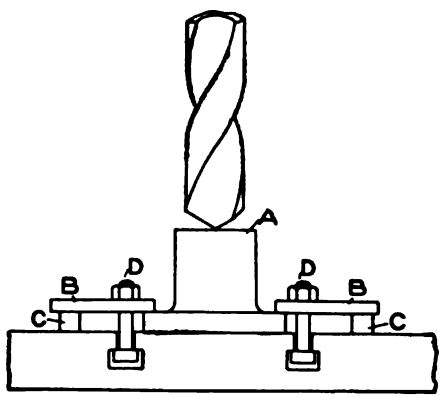


Fig. 171.

work as possible. When the nuts are screwed down, they then put the greatest available pressure on the work and hold it fast. The strap B is made of flat iron. It has one or more holes drilled in it to permit the passage of bolts.

Another method of holding work in the drill press is by means of a post. This is shown in Fig. 172. It consists of a post A, set loosely in one of the holes in the table. As the drill is forced against the work, it tends to turn the latter with it. When the work strikes the post, it is stopped and held while the hole is drilled. This will not hold the work perfectly steady. It allows the latter to move with the eccentricity of the motion

of the drill, but it is in very common use where extreme accuracy is not essential. For example, where a finished bolt is to be used with a driving fit, the work must be securely fastened so that the diameter of the hole may be true. Where a machine bolt made of rough iron is to be used, the hole is drilled $\frac{1}{16}$ inch larger than the normal size of the bolt. Here accuracy is not

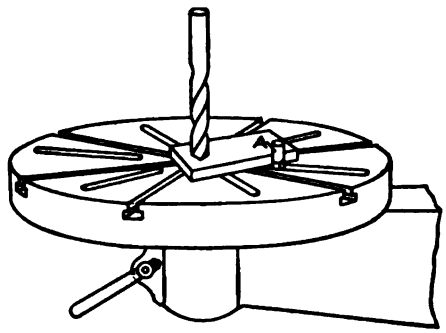
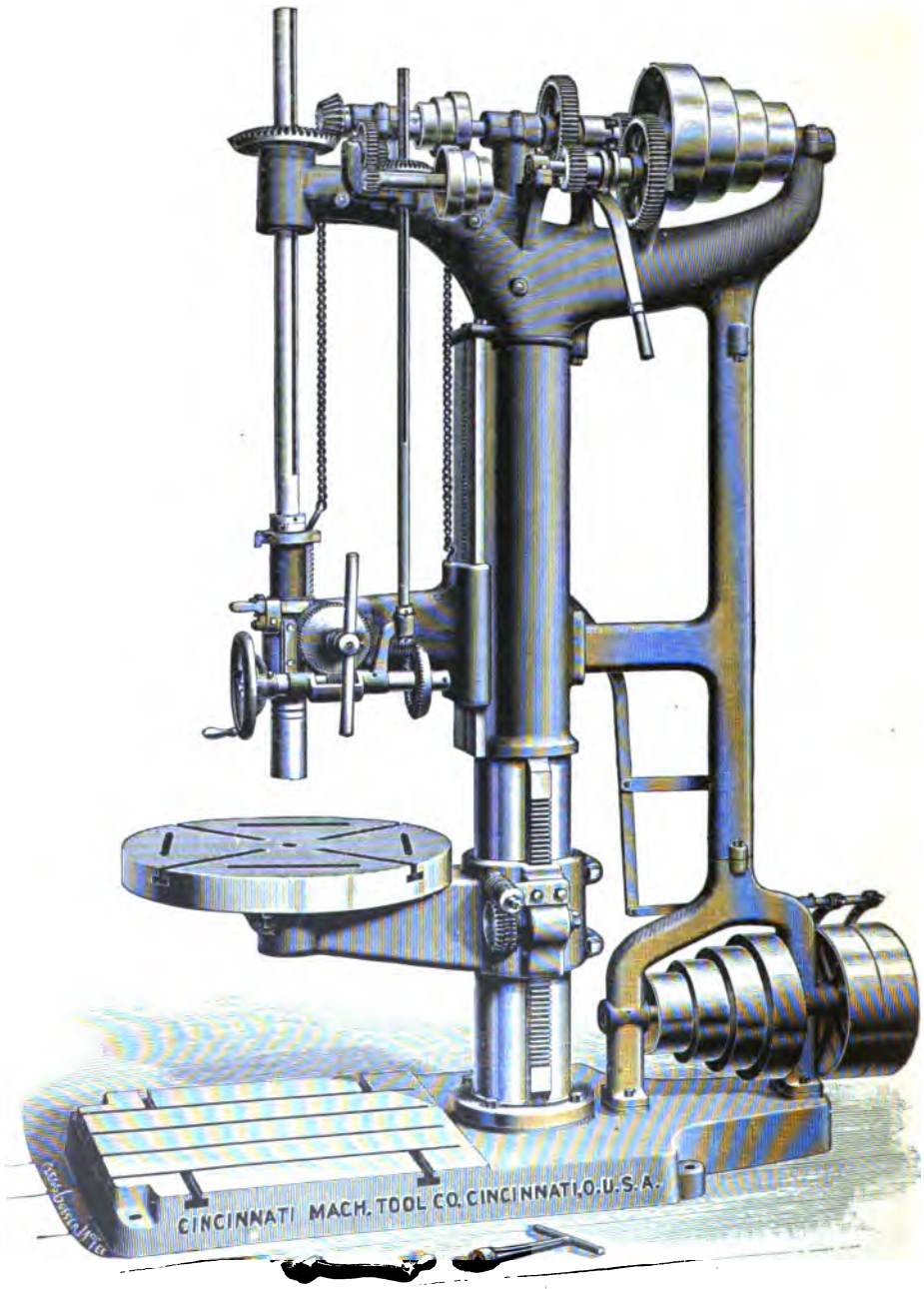


Fig. 172.

even attempted; a variation of $\frac{1}{32}$ inch in the diameter of the hole is of no account. Therefore, in such cases, the work may be allowed to merely rest against the post.

This question of holding the work does not apply to drills of the multi-spindle class. It is evident that the tendency of one drill to rotate the work is *counteracted by the action of another drill.* Therefore, no holding devices are needed on drills of more than one spindle.



36-inch Heavy Pattern Upright Drill with Sliding Head, Back Gear, Power Feed, Automatic Stop and Quick Return.

THE PLANER.

NEXT to the lathe, the planer is the most important tool in the machine shop. As the name indicates, it is used for finishing flat surfaces. In the ordinary planer, the work is moved and the tool is at rest. A common form of this tool is shown in Fig. 173. It consists of a bed A upon the upper surface of which suitable guides or ways are planed. The platen B is made to travel back and forth upon these ways. The platen has a rack on its under surface into which the gear C meshes. This gear is driven by a train of gears from the shaft carrying the pulley D. The tool is carried on the tool-head E, where it can be given a slight vertical motion or feed. This tool-head may be fed across the machine by the screw in the cross-rail F. The latter may be raised and lowered by the shaft and gearing shown at the top. This gearing turns two vertical screws running in nuts attached to the cross-rail.

The reciprocating motion of the platen is obtained as follows: the pulleys D and G are driven in opposite direction by belts. Either one may be connected to the shaft on which they turn by a clutch which is operated by the bell-crank lever J. On the platen there are two adjustable dogs HH. These are set so that, when the work has just cleared the tool in either direction, one of them will strike against the upper end of the lever I. In the illustration, if the platen is moving in toward the right-hand dog, H will have struck the lever. As the platen continues to move, the lever I is carried to the right and the clutch connection fastening the forward pulley to the shaft broken and that of the return made. The motion is then reversed and continues until the left-hand dog strikes the lever I and again changes the motion.

Ordinarily the tool cuts only when the platen is moving toward the right Fig. 173. As a result of this condition, the

platen is made to move more rapidly in the direction of the arrow than in the reverse. This is accomplished by varying the speeds of the pulleys D and G. The usual ratio of the speeds of these pulleys is from 1 to 2, to 1 to 5.

The feed of the tool is accomplished by a friction clutch driving the vertical rack K. This acts only at a point near the

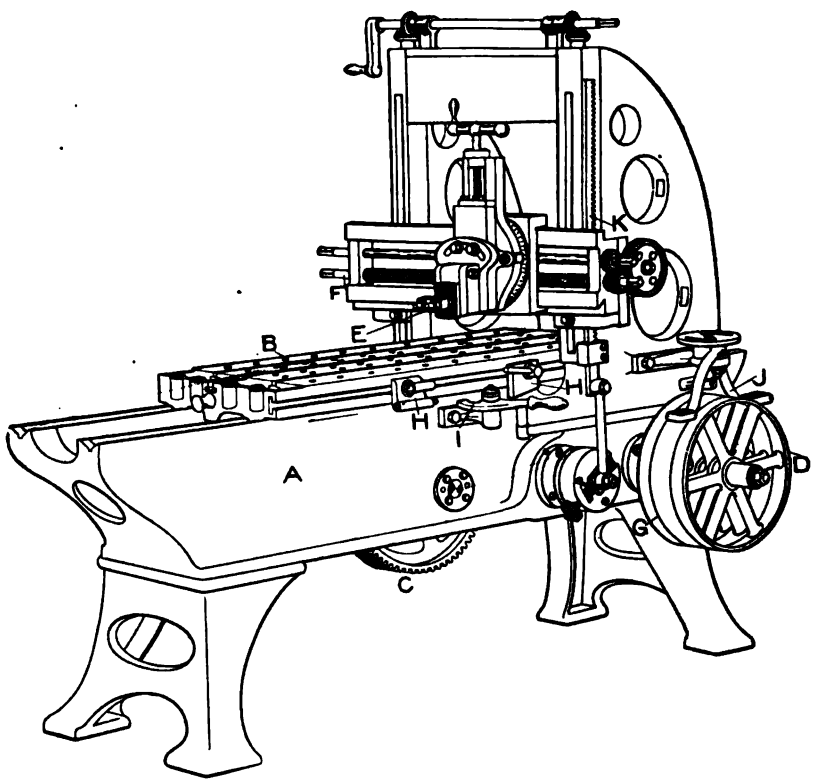


Fig. 173.

end of the travel of the platen. It is so arranged that any vertical or horizontal feed may be given to the tool.

Planers are made in a great variety of sizes and styles. Very frequently there are three driving pulleys placed side by side on the same shaft, the central one of the three keyed to the

shaft. The reversal of the motion of the platen is obtained by shifting one or the other of the belts onto the central pulley.

Planer Tools. The tools that are used upon planers do not differ essentially from those described for lathe work. The same rule applies regarding the holding of the tool. It should project as short a distance as possible beyond the point of support.

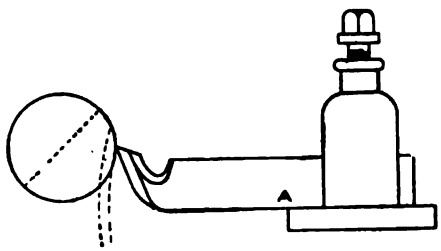


Fig. 174.

When there is an excessive projection, care should be taken that the tool is so set that it will not spring into the work. On the lathe this can be prevented by setting the point of the tool on a line with the center. In Fig. 174 the tool tends to spring and turn about the point A as a center. The dotted line at the point shows how this tends to throw it into the work. The same thing is shown in the planer tool in Fig. 175. This tendency can be overcome by forging the tool so that the cutting point is behind a perpendicular from the point of support, as shown by the dotted lines in Fig. 175. In the latter case the spring of the tool tends to take it out of the work.

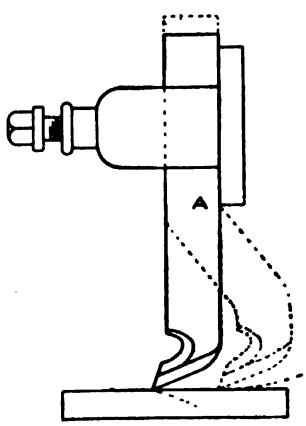


Fig. 175.

Holding the Work. The work is usually held on the planer by clamping it down with straps in a manner similar to that shown in Fig. 171. Where the whole upper surface is to be planed over, holes are sometimes drilled in the sides, into which the rounded ends of straps are set.

It is impossible to give more than general directions for clamping work on a planer. A great variety of blocking, clamps and bolts must be used; such attachments being suited to the work in hand, and requiring an outlay of money which seems to be out of proportion to the appearance of the collection. It

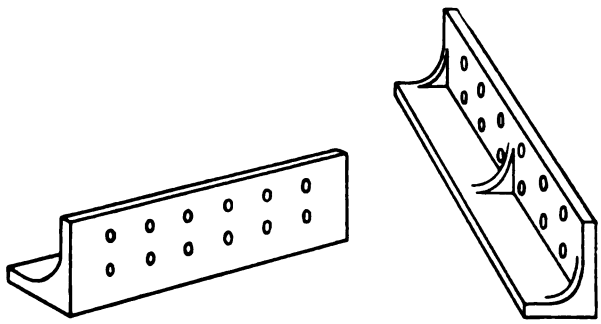


Fig. 176.

should be sufficient to say that the work must be carefully set, strongly clamped and braced to prevent movement by the tool; the clamping should not distort the work. As all castings and forgings change their shape when the surface is removed, it is considered good practice to release the clamps before the finishing

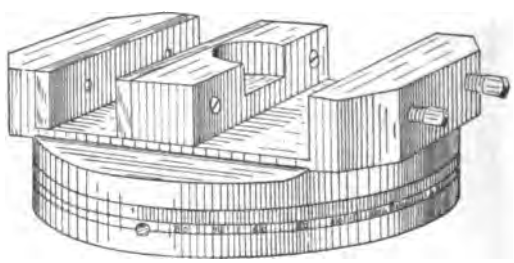


Fig. 177.

cut, in order that the piece may assume its final shape, and then reclamp it without distortion.

Angle irons or knees, as shown in Fig. 176, may be considered as an auxiliary table with a surface at right angles to the

main table. Many useful applications of these holding devices will suggest themselves.

Another method of holding work is by using a vise such as is shown in Fig. 177. The body is bolted to the platen and the work is held between the jaws.

Planer centers, as illustrated in Fig. 178, are very useful in machining parts where accurate circular spacing is desired, or where projecting lugs prevent turning in the lathe.

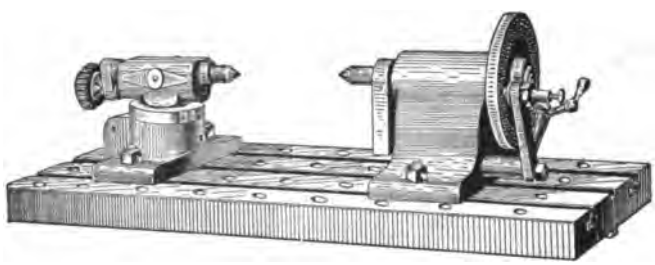


Fig. 178.

The Plate Planer. A special form of planer extensively used in boiler shops and shipyards is the plate planer, Fig. 179. It is used for planing the edges of long plates. The plate is securely fastened between the clamps A and the bed B. The tool is held in the carriage C, which is moved to and fro by the screw D. The screw is driven by the gear H, that meshes with a pinion keyed on the shaft to which the motor is geared. The reversal of motion is obtained by shifting the clutch K. The tappets M for moving the shifting gear are upon the shaft I. They are struck as the carriage approaches the end of its stroke. Unlike the ordinary machine shop planer, the plate planer has no quick return stroke, but has a tilting tool which allows stock to be removed when moving in either direction. Devices of this character have often been tried on regular metal planers, but seem to be satisfactory only when the whole face of the work can be covered at a single stroke of the tool.

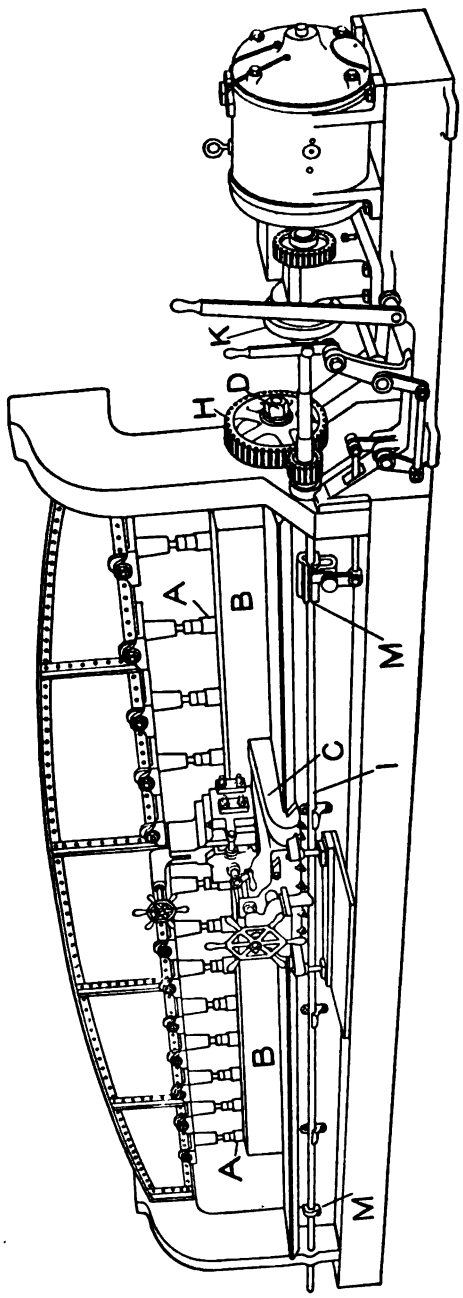


Fig. 179.

THE SHAPER.

For light work the shaper or shaping planer, Fig. 180, is extensively used. It possesses the advantage of rapidity of action. In this machine, as in the plate planer, the tool moves while the

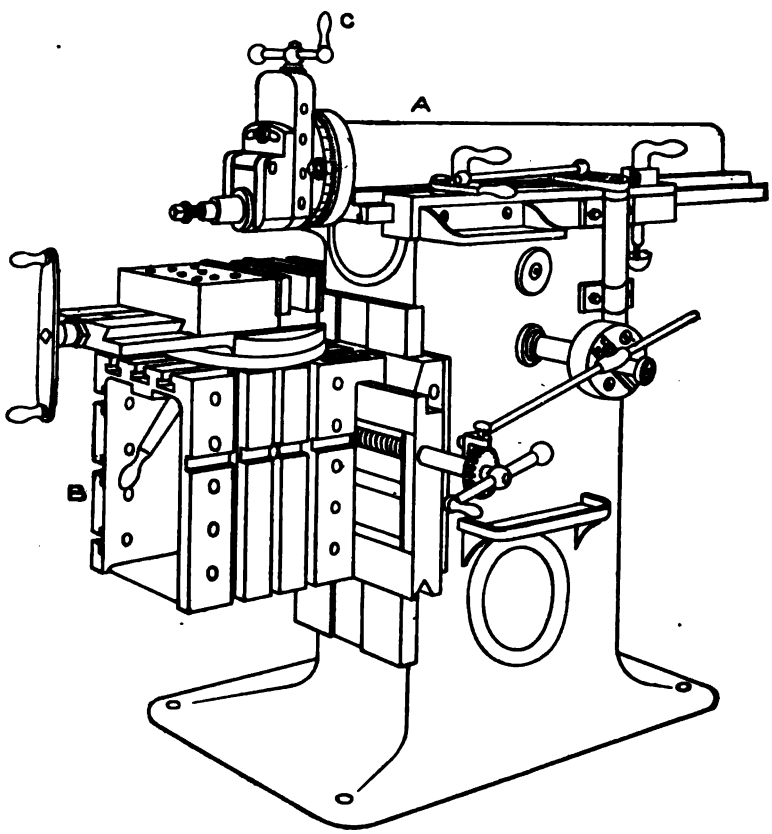


Fig. 180.

work is at rest. A suitable mechanism causes the ram A to move to and fro. When moving toward the left, the tool is cutting. As in the ordinary planer, the cutting speed is less than the return.

The work is held on the table B, which may be adjusted to any convenient height suited to the work to be done. The tool is also allowed a limited vertical adjustment in the slide by turn-

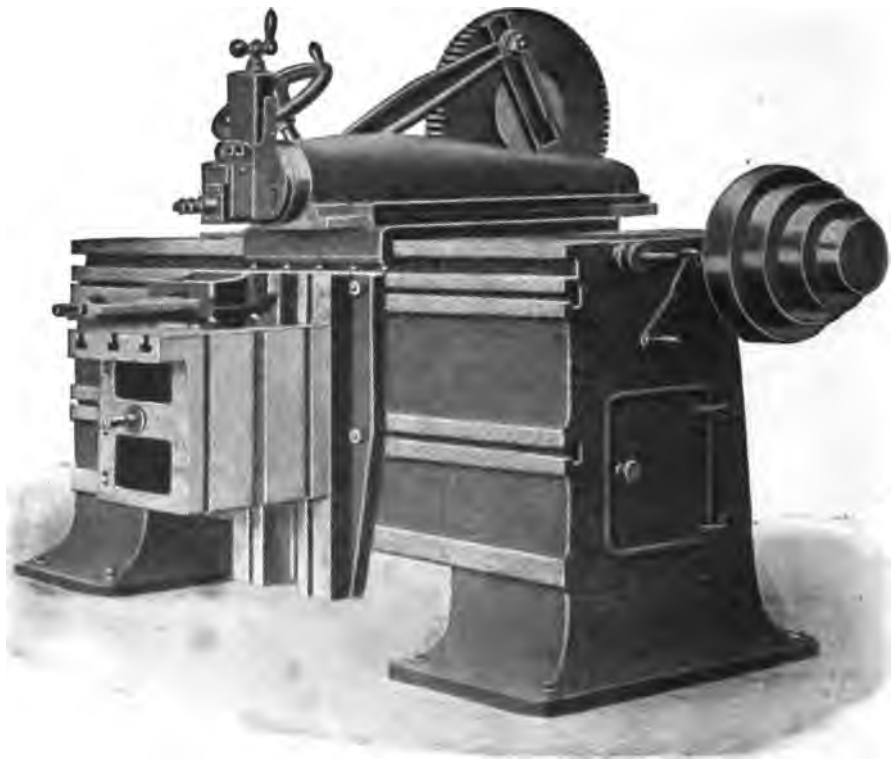


Fig. 181.

ing the handle C. This is the ordinary method of obtaining the vertical feed.

The horizontal feed is obtained by moving the table B sidewise. In some shapers it can also be moved vertically to feed to or from the tool; in others the horizontal feed is obtained by causing the tool with the reciprocating parts to move sidewise.

The style of machine shown at Fig. 180 is called the pillar shaper, but where the tool and ram move sidewise it is called the

traverse shaper; see Fig. 181. The character of the work done on the shaper and the planer is identical, but as a rule, the shaper is used for the smaller and more delicate parts which could not be handled quickly on the planer. The shaper has the additional advantage of a change of speed which allows small pieces, especially of the softer metals, to be machined at a maximum rate.

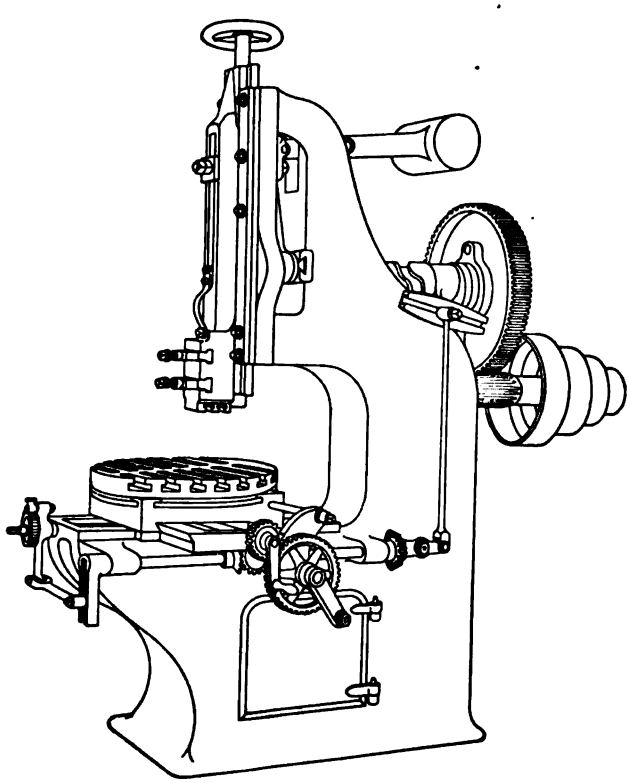


Fig. 182.

Slotter. Another machine tool which is not used as commonly as its many good qualities would seem to warrant is the slotter, Fig. 182. It is, in reality, a shaper with the tool moving vertically instead of horizontally. It is used for working on heavy pieces, and especially in places where an irregular contour is to be formed. The thrust on the tool is vertical, and it must

be very stiff. The work done frequently partakes of the nature of the forming of the inside of the hole where the tool must project the whole length of the cut below the bottom of the head. Such a case is that of the slotting of locomotive frames. The best type of tool for such a class of work is a strong bar, as shown in Fig. 183. The bar is held in the head of the tool just as any tool would be. Near the lower end it carries the cutting tool, which may be fastened by a set-screw or wedge. Such a tool should always be used when it is possible. It has the advantage of being stiffer and less likely to spring than a forged tool.

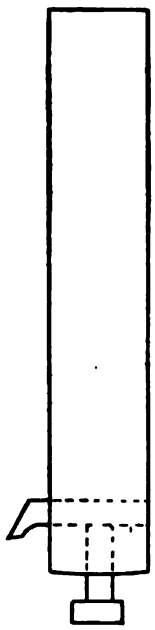


Fig. 183.

The tool used in a slotting machine differs from that used in the lathe or planer in that the direction of the cutting motion is different. Fig. 184 illustrates a slotting tool to be used for doing such work as the cutting of keyways in the hubs of pulleys. It will be seen that if the tool is moved in the direction of the arrow, the face B becomes the one against which the chip bears. It, therefore, corresponds to the top of the lathe tool. The sharper the slope given to the face B, the keener the edge, just as increasing the rake of the lathe tool increases its sharpness. The face A must also be cut away as indicated. This corresponds to the

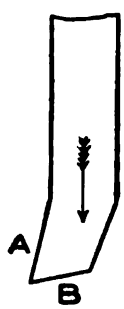


Fig. 184.

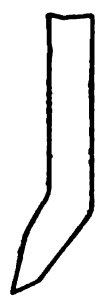


Fig. 185.

clearance of the lathe or planer tool. It is quite possible, at times, to give these tools a larger amount of rake. Such a form

is shown in Fig. 185. The shape of this tool is such that it is very strong in the direction of the thrust, besides having a keen cutting edge.

THE MILLING MACHINE.

The Milling Machine is a machine used for the finishing of flat or curved surfaces by the use of rotating cutters. This method of doing work consists in passing the work beneath a rotating cutter that removes the metal in the same way as does the surface planer commonly used for planing wood. The machine, Fig. 186, consists of a heavy frame carrying a horizontal spindle A; the face of the frame is at right angles to the spindle, and carries a vertically moving knee B, with a top face parallel to the spindle. On this knee is carried a saddle C, capable of movement to and from the frame. On the saddle rests the platen D, which moves horizontally at right angles to the spindle. The combination of these motions allows any part of the platen to be placed under the cutter at any height within the range of the machine.

The work may be held in several ways. It can be clamped to the table as on the planer and shaper; it can be held in the vise, shown at the bottom of Fig. 186, which is bolted to the table; it can be held between the centers of the dividing head and the tailstock, Fig. 186; or the center and faceplate can be removed from the dividing head, a three or four jawed chuck screwed on the nose of the spindle, and the work held therein at any angle from horizontal to vertical. This use of the dividing head does not prevent its rotation.

The Care of the Machine. The milling machine, and in fact all the machines of the shop, can only do efficient work when they are well cared for. An important element in this case is that they should be kept clean and well oiled.

Great care should be exercised that chips do not get into the holes in the spindles or between the arbor collars.

When at work, the milling cutter is kept flooded with oil or a solution of sal soda as already specified for lathe work.

Oil is used in milling to obtain smoother work, to make the mills last longer, and, where the nature of the work requires, to wash the chips from the work or from the teeth of the cutters.

It is generally used in milling a large number of pieces of steel, wrought iron, malleable iron, or tough bronze. Frequently when only a few pieces are to be milled, it is not used, and some steel castings are milled without oil; also in cutting cast iron it is not used. For light, flat cuts it is put on with a brush, giving the work a thin covering like a varnish; for heavy cuts it should be led to the mill from the drip can that is usually sent with each

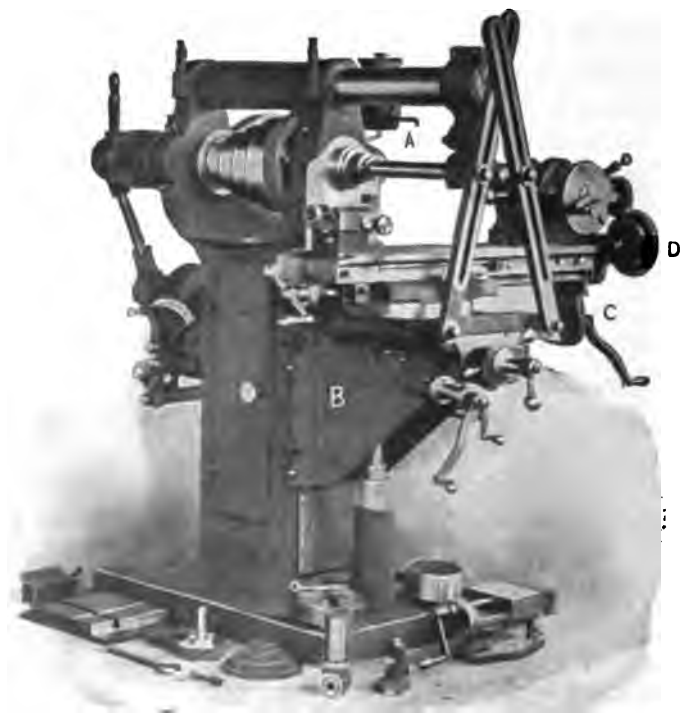


Fig. 186.

machine, or it should be pumped upon or across the mill in cutting deep grooves, in milling several grooves at one time, or, indeed, in milling any work where, if the chips should stick, they might catch between the teeth and sides of the grooves, and scratch or bend the work.

The Brown & Sharpe Co. recommend the use of lard oil in milling. Any animal or fish oil, however, may be used, and then

separated from the chips by the use of a centrifugal separator, or by dumping into a tank of water. In the latter method, the chips fall to the bottom and the oil rises to the top, whence it may be drawn off with but little waste.

Messrs. Brown & Sharpe Co. are authority for the following statements regarding

The Speed of Mills. "It is impossible to give definite rules for the speed and feed of mills. The judgment of the foreman or man in charge of the machine should determine what is best in each instance.

"As usually the highest possible speed and feed are desirable, it pays to increase them both until it is seen that something will break or burn, and then reduce to a speed and feed of safety. Sometimes the speed must be reduced and yet the feed need not be changed.

"The average speed on wrought iron and annealed steel is, perhaps, 40 feet per minute, which gives about sixty turns per minute with mills $2\frac{1}{2}''$ in diameter. The feed of the work for this surface speed of the mill can be about $1\frac{1}{2}''$ per minute, and the depth of the cut about $\frac{1}{16}''$. In cast iron, a mill can have a surface speed of about 50 feet a minute, while the feed is $1\frac{1}{2}''$ per minute and the cut $\frac{3}{16}''$ deep. In tough brass, the speed may be 80 feet, the feed the same as in cast iron and the chip $\frac{3}{32}''$

"As small mills cut faster than large ones, an end mill, for example, $\frac{1}{2}''$ in diameter, can be run about 400 revolutions per minute with a feed of 4'."

Addy, an English authority, gives as a safe speed for cutters of 6" diameter and upwards:

Steel,	36	ft.	per	minute	with	a	feed	of	$\frac{1}{2}''$	per	minute.
Wrought Iron,	48	"	"	"	"	"	"	"	1"	"	"
Cast Iron	60	"	"	"	"	"	"	"	$1\frac{1}{3}''$	"	"
Brass,	120	"	"	"	"	"	"	"	$2\frac{2}{3}''$	"	"

He also gives a simple rule for obtaining the speed: the number of revolutions which the cutter should make when working on cast iron = 240 divided by the diameter in inches.

The following table has been prepared by Messrs. Brown and Sharpe to give the speed, feed, and depth of cut that can be obtained with a machine similar to that illustrated in Fig. 186.

SURFACE MILLING OF CAST IRON.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of Cast Iron in Inches.	Under Scale of Cast Iron in Inches.
3	42	34	1/16	1	6 5/8	8 7/8
	42	34	1/8	1	4 1/8	6 1/8
	42	34	1/16	2	6 5/8	8 7/8
	42	34	1/8	2	2 1/8	4 1/8
	42	34	1/16	3	6 5/8	8 7/8
	42	34	7/16	3	1 3/8	2 3/16
3 1/2	42	40	5/32	8	4 1/8	6 1/8
	42	40	1/8	3 1/2	2 1/2	3 1/2
4 1/2	42	50	1	2	4 1/8	6 1/8
	42	50	1	4	3 1/2	4 1/8
	42	50	1	6	2	2 1/8
	42	50	1/8	6	4 1/8	6 1/8
	42	50	1/32	12	1 3/8	2

SURFACE MILLING OF SOFT MACHINERY STEEL.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of S. M. S. in Inches.	Under Scale of S. M. S. in Inches.
3	38	30	1/16	1	6	8
	38	30	1/8	1	1 1/8	1 7/8
	38	30	1/16	2	2 3/8	3 1/8
	38	30	1/8	2	7/8	1 3/8
	38	30	1/16	3	1 1/8	1 7/8
	38	30	1/8	3	3/4	1 1/8
3 1/2	38	35	1/16	8	1 7/8	3
	38	35	1/8	8	3/4	1 1/8
4 1/2	25	30	1/16	3	4	5
	25	30	1/16	5	2 1/2	4 1/2
	25	30	1/8	5		3/4
	25	30	1/16	10	1 3/4	2 1/2
	25	30	3/16	10	1/2	7/8

END OR FACE MILLING OF CAST IRON.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of Cast Iron in Inches.	Under Scale of Cast Iron in Inches.
½	382	50	1/16	½	23	35
	382	50	⅛	½	7	11
1	191	50	1/16	1	30	40
	191	50	⅛	1	3	5½
1¼	109	50	¼	1¼	17	23
	109	50	⅜	1¼	3⅝	4⅛
5	42	55	¼	5	2⅝	4⅛
16	10	45	¼	16	⅞	1

FACE MILLING OF SOFT MACHINERY STEEL.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of S. M. S. in Inches.	Under Scale of S. M. S. in Inches.
½	267	35	1/16	½		
	267	35	¼	½		
1	152	40	1/16	1	8	4¼
	152	40	½	1		
1¼	87	40	1/16	1¼	2¼	4¼
	87	40	¾	1¼		1¼

The milling cutter, Fig. 187, is made of tool steel. It is carefully turned and cut, and then hardened and tempered as a lathe tool. It consists of a series of teeth cut in the form of a long screw. It is revolved against the motion of the work, as in Fig. 188. The arrows show the direction of motion of the two pieces. With the motions as indicated, the work has to be forced against the cutter. There is no tendency to draw the work be-

neath the cutter. Should the motion of the cutter be reversed while that of the work remains the same, the former would have a tendency to draw the latter beneath it. Then, if any of the fastenings should become loose, the work would be drawn rapidly forward and the cutter probably broken.

Besides the face mill shown in Fig. 187, a very different style, known as the end mill, is in common use. It is shown in Fig. 189. It is supported directly by the spindle, and can be used in many places where the face mill could not be applied.

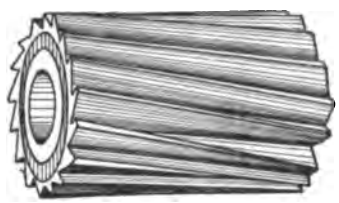


Fig. 187.

The milling machine is extensively used in the place of the planer. A special form of this tool, known as the slab miller, is now made. It is built of the same general form as the planer. Instead of the cross rail, it has an arbor carrying a milling cutter. Such machines are used for finishing valve faces and similar work. For work of this class it is much more rapid than the planer. The same work can be done in from one-half to one-third the time that it can be upon the planer.

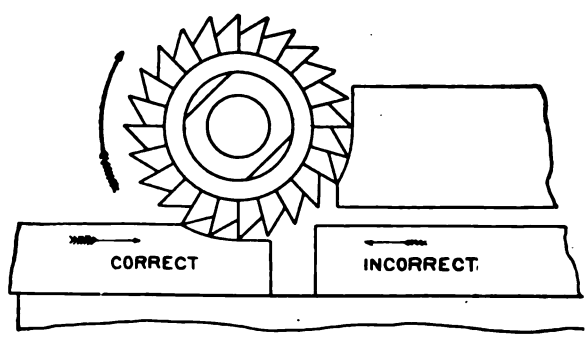


Fig. 188.

The milling machine is also valuable for finishing irregular surfaces. The outlining of links for locomotives is an example. Fig. 191.

It is also used for cutting the teeth of gears. For this class

of work, the gear to be cut is placed upon an mandrel and fed against the tool. The cutting portion of the tool has the exact shape to be given to the space between the teeth, Fig. 191. In

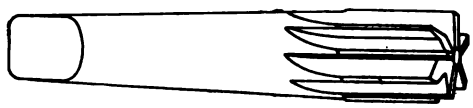


Fig. 189.

order that the gear may be accurately and quickly set, an index head is used, which is shown in Fig. 192. The mandrel upon which the gear is mounted is hung upon the centers AA, and firmly fastened to the spider B. The index plate C is geared to the spindle that carries the spider B; the index plate is drilled with a large number of holes. These holes are arranged in circles, and are accurately spaced at equal distances apart. The arm D carries a stem E, having a knurled head at one end and a pin at the other. The pin is held in one of the holes of the index plate by a spring. The arm D can be swung to any desired position, relatively to the index plate, and there fastened.

Fig. 190.

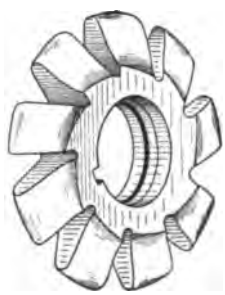


Fig. 191.

When a gear is to be cut, the arm D is swung so that the pin is opposite a row of holes whose number of teeth is to be cut. Thus, suppose a gear with 45 teeth is to be made. The pin may be set opposite the circle of 90 holes. The pin is placed in one of them and the first space cut. It is then withdrawn, and the plate with the gear turned until the pin enters the second

hole from the one in which it had previously been placed. The second space is then cut. This process is repeated by placing the pin in each alternate hole until the whole gear has been cut. In like manner gears with any number of teeth may be cut.

The milling machine has made interchangeable work a possibility. By interchangeable work is meant such classes of manufactured product that any piece is so exactly duplicated that it can be used in any one of a number of similar machines. This is the method followed in making guns, sewing machines, and the like. Each piece is made separately in the milling or other machine, and then all parts are put together or assembled, without further work being done upon them. There is, however, a limit

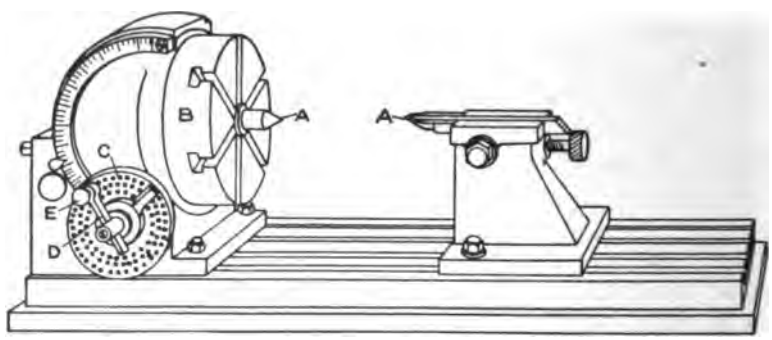


Fig. 192.

of accuracy even in this work. This limit is usually placed at about .002 inch. Thus, if a piece is to be milled to a nominal dimension of 1 inch, it may actually be 1.001 inch or .999 inch. This is sufficiently close for ordinary working.

THE GRINDING MACHINE.

When greater accuracy than that obtainable on the milling machine or the lathe is required, recourse is had to grinding. One type of machine used for this purpose is shown in Fig. 193. With such a machine round surfaces may be ground so that the variation from the nominal diameter is less than .0001 inch.

The grinding machine consists of a strong base A, upon which there is mounted a headstock B and a tailstock C similar in action to those of an ordinary lathe. Back of this there is an emery wheel driven by a separate belt. The principle of operation, for round surfaces, is that the part to be ground is put upon the centers, and driven exactly as in the ordinary lathe. The only additional precaution to be taken is that the driving apparatus should be secure, so that there is no looseness of the parts. This insures a continuous motion for the piece with no possibility of any black-lash. The piece turns towards the operator, and the emery wheel runs in the same direction. The two surfaces of wheel and work in contact are, therefore, moving in opposite directions.

The head- and tailstocks are mounted upon a traveling table D; this table moves back and forth in the same manner as the platen of a planer. It is made to stop automatically at each end of the stroke.

When work is being done, the piece is centered, with its axis parallel to the line of travel of the table. With the piece and emery wheel in motion, the former travels to and fro in front of the lathe. The wheel is then gradually moved forward until it has ground the work down to the size required.

It is not intended that large amounts of metal shall be removed by this machine. Its object is to reduce to accurate dimensions the work that has already been turned in the lathe. The proper method to pursue is to turn the piece to as nearly the required diameter as possible in the lathe, care being taken that it is left a trifle large. This may be on each 2 inches of diameter. The surplus metal may then be removed by grinding. In the machine illustrated in Fig. 193, the transverse movement of the wheel-stand is adjusted by a hand-wheel graduated to read to on the diameter of the work. The machine is also provided with an automatic cross-feed, which gives a range of advance of the wheel varying from .00025 inch to .004 inch at each reversal of the table. This feed is, furthermore, so arranged that it can be automatically released at any point.

This method of finishing is also used for pieces that have been case-hardened. Case-hardening always warps the metal to

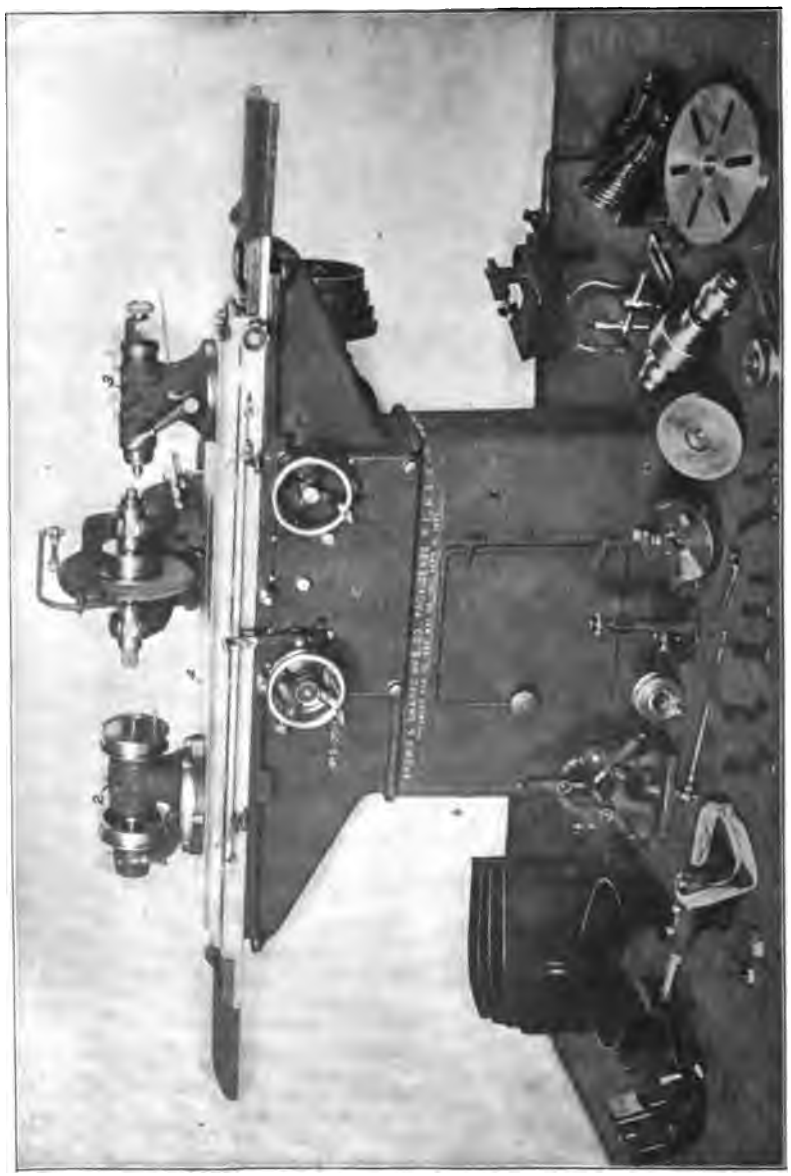


Fig. 198.

which it is applied. Grinding is resorted to in order to reduce it to the proper shape. An example of this may be taken in the method used in the manufacturing of wrought-iron locomotive crank-pins. The pin is forged and turned to as near the working size as possible. It is then case-hardened and ground to exact truth and dimensions.

Grinding is also used for truing work that comes from the lathe. The lathe does not turn its work round, owing to difference in the density of the metal, the variation of the cutting speed, the dulling of the tool, the lost motion on the centers and in the spindle, and the springing of the work itself due to the pressure of the tool.

SPEED OF GRINDING WHEELS.

Diameter of Wheel in Inches.	Maximum Revolutions per Minute.	Diameter of Wheel in Inches.	Maximum Revolutions per Minute.	Diameter of Wheel in Inches.	Maximum Revolutions per Minute.
1	19,000	5	4,400	14	1,580
1½	12,500	6	3,700	16	1,380
2	9,000	7	3,160	18	1,230
2½	8,800	8	2,770	20	1,100
3	7,400	9	2,460	22	1,000
3½	6,300	10	2,210	24	920
4	5,500	12	1,850	26	850

The grinding machine remedies this to a great extent. Partly because only a very slight pressure is brought against the work; partly because of the greater delicacy of adjustment of the grinding machine as compared with the lathe.

The method of grinding flat surfaces is practically similar to that used for round. The work is bolted to the table and moved to and fro beneath the emery wheel, which is given a transverse movement so as to cover the whole of the surface to be operated upon. The surface speed of the wheel may range from 3,000 to 5,000 feet per minute.

The above table gives the maximum speeds of caborundum wheels of various diameters.

The accuracy of grinding renders the use of fine measuring

tools a necessity. The micrometer caliper, especially with the vernier graduation, is best suited for this work.

While grinding is the only method of finishing some materials, such as hardened tool steel, and the most accurate way for finishing any kind of stock, its value as an economical method is just beginning to be recognized. The general method of finishing lathe work has been to take a roughing cut with about $\frac{1}{16}$ inch feed, then a finishing cut with about $\frac{1}{100}$ inch feed, and then file to remove the tool marks. In the majority of cases it is more economical as well as more accurate to take a roughing cut with $\frac{1}{8}$ inch feed to within $\frac{1}{32}$ inch of the size, and then finish by grinding.

In some cases it is possible to get excellent results by grinding to size direct from the bar without previous turning.

Lapping is a term applied to a particular method employed in the grinding out of holes. The lap consists of a cylinder of soft metal run rapidly inside the hole to be lapped and covered with emery and oil at the same time. The surface of the lap should invariably be of soft metal. It may be made of copper, or it may be an iron bar with a covering of lead or tin. It should be turned slightly tapering at each end, so that it will enter the hole. At the middle, it should be a tight fit.

The end of the bar is run through the hole and set on the lathe centers with a dog to drive it like an ordinary mandrel. It is covered with oil and sprinkled with emery. The lathe is then run at a high speed and the work moved to and fro over the lap. Light pieces may be held in the hand. When this is done, care should be taken to turn the piece so that the grinding may be even over the whole circumference. The tendency is, when holding work in the hand, to allow it to rest upon the top of the lap; this causes the grinding to be done on one side of the hole unless the piece is frequently turned. Laps may be used for grinding holes true and parallel. For this purpose the work should be accurately centered with the lap and firmly bolted to the lathe carriage. The lap is then run at a high speed and the work moved to and fro over it.

Laps are sometimes used for grinding flat surfaces. In such cases they are in the form of disks. They are put on the lathe

spindle in the place of the faceplate. The work is then pressed against the disk. As the outer edge of the disk has a higher speed in feet traveled per minute than those portions nearer the center, the grinding is more rapid at the edges. The work must, therefore, be constantly turned if it is held in the hand. The best way is to clamp it firmly on the lathe carriage, and press it against the lap by means of the hand feed.

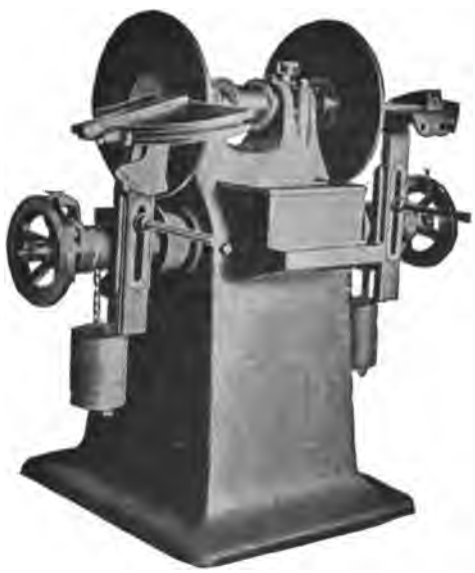


Fig. 194.

Laps for flat surfaces have grown in favor so rapidly that special machines have been made to do this work. The construction of the disk grinder can be so readily seen from the illustration (Fig. 194), that a detailed description does not seem necessary. For finishing small flat surfaces, especially those which have been hardened, this machine has become an important factor in the modern shop.

LAYING OUT WORK.

Laying out work is one of the most important details of machine shop practice. Ordinarily all work is laid out. The exceptions are where certain pieces are worked from templets, and in these cases the templet is laid out from certain points on the casting, forging, punching, or whatever is used for the work in hand.

The simplest form of laying out work is to be found in the centering of round bars that are to be turned in the lathe. In this case the end of the piece is chalked. Use a pair of hermaphrodite calipers, set the points A and B so that their distance apart is a little more than the radius of the piece. Place the caliper leg at three points on the circumference, A, B, and C (Fig. 195), and describe from each the arcs of circles A′A′, B′B′, and C′C′, respectively. Then with the prick punch mark the point indicated by the small circle in the center. This will be the center. To test its accuracy, place the divider leg in the prick punch mark and see if the caliper leg will just touch the bar over its whole surface.

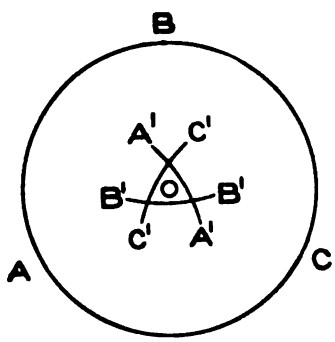


Fig. 195.

Before drilling, the center should be emphasized with a center punch.

The center square may be used for this operation, as the center can be easily located at the intersection of two diameters drawn nearly at right angles. In some cases it is better to lay the shaft in V blocks on a plate and use the surface gauge, drawing at least two lines through the center of the piece.

It is usually necessary to cover the surface of the work where lines must be visible, with chalk, white lead, or copperas, before any laying out can be done; but in cases of this kind it is usual to mark directly upon the end of the bar. Before drilling, the center should be emphasized with a center punch.

The locations for holes should be at the intersection of lines in order to be plain. After marking the center with a prick punch, take a pair of dividers and scribe a circle on the prepared surface concentric with the center already located. This circle should be about the diameter of the hole to be drilled, and in many good shops it is the custom to draw another circle concentric with the first and about $\frac{1}{8}''$ larger in diameter. This outer circle is called the reference circle, and is for the benefit of the inspector when it becomes necessary to place the responsibility for a misplaced hole. These circles may be marked with at least four prick punch marks, as shown in Fig. 168, in order to indicate the position of the circle in case of the obliteration of the line. The center is then deepened by the center punch and the hole drilled. In laying out work, the first thing to do is to "snag" the work; that is, remove the ridges of the casting caused by the pattern being made in two or more parts. For small castings a coarse file is generally used, while for large work the cold chisel is used. In many shops the cold chisel is operated by compressed air.

In laying out work for the planer and milling machine great care must be exercised. It is necessary that there should be a base line to which the lines may be referred. It depends on the character of the work as to how this should be done. Sometimes it is quite sufficient to lay off the base line parallel to one side of the casting or forging. If the side thus used is to be finished, then the base line should be located at the proper distance from it to allow for the finishing. The amount required varies with the character of the casting or forging; this has been fully explained. Usually there is some outline of the rough piece that will serve as a guide.

As an example of the laying out of work, take the valve and steam chest seats shown in Figs. 196 and 197. The work is to be done on a planer. The cylinder has probably been bored. It is then placed on the planer, and so set that the center line through the cylinder is parallel to the platen of the planer. The first machine work to be done is the taking off of the roughing cut from the face A. This face is to be planed down to a certain height above the cylinder center; this height may be marked on

the edge of the valve seat by the prick punch mark B. If the surface C is to be planed at the same time, its height is indicated by the prick punch mark D. These points may be located by means of the surface gauge. Set the gauge on the platen and

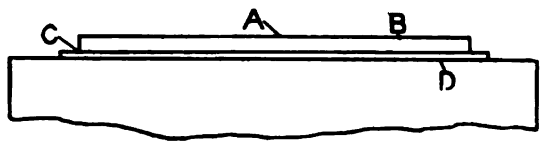


Fig. 196.

elevate the point to the proper height. Move it so that it will touch the side of the casting at the proper point, and make the marks B and D accordingly. When the surfaces A and C have

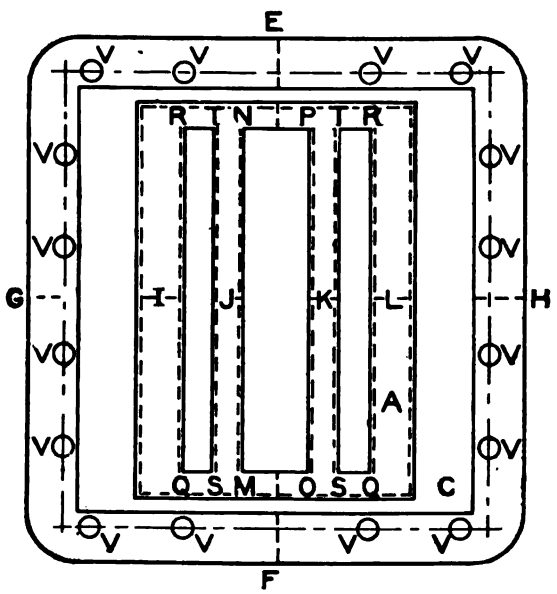


Fig. 197.

received the roughing cut, the plan may be laid off as in Fig. 197. With a square having a suitable length of blade, locate the points G and H directly over the center line of the cylinder. Cover the

surfaces A and C with chalk where lines are to be drawn. Draw the lines I, J, K and L on the surface A, between G and H. Through the center of the side of the exhaust port draw the lines E and F at right angles to GH. This is done with a scriber. Lay off half the width of the exhaust port on either side of E and F, and draw the lines MN and OP parallel to E and F. In like manner, draw the lines QR and ST for the limits of the steam ports. All of these lines are to be emphasized by the use of prick punch marks as indicated.

If the sides of the valve seat are to be finished, the line to which the metal is to be cut is indicated in the same manner. Finally the holes VVV, etc., for the holding down studs of the steam chest, are to be laid out. The center lines are first drawn; then the centers of the holes are marked. After which the circles for the holes are drawn as already described.

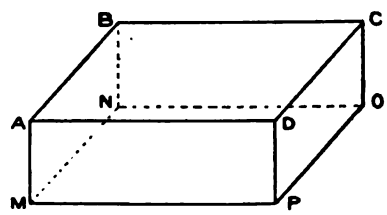


Fig. 198.

Work is rarely laid out for the lathe. It is not necessary that it should always be done for the planer. Laying out is employed where accuracy is essential, and, where it is possible to secure the proper dimensions, with the piece to be operated upon in position on the machine.

The man who has charge of the work of laying out should have some knowledge of the elementary principles of geometry, he should also have some knowledge of drawing, and should, of course, be able to read drawings.

A few general suggestions may be given regarding work to be finished in the vise on either the planer, shaper, or the milling machine, where several faces are to be finished at right angles to one another. Referring to the rectangular block of Fig. 198, the block is first placed in the vise with the face MNOP down, and the face MADP against the fixed jaw. The face ABCD is then machined, and the work turned so that ABCD is against the fixed jaw and MADP down. With the block in this position, NBCO is worked, making NBCO at right angles to ABCD. With ABCD still against the fixed jaw, and

NBCO down, surface MADP is next worked. This brings two edges at right angles to the same side and parallel to each other. Then, placing ABCD down and either MADP or NBCO against the fixed jaw, surface MNOP is generated parallel to ABCD. This leaves the ends to be finished. The vise is swung so that the fixed jaw is at right angles to the line of motion of the tool, and on the planer and shaper, they are finished by using the vertical feed. In the two last named tools, the tool holder is swung so that the tool will clear the work easily on the return stroke.

In working cast iron, it is well to chamfer the edges with a file. If this is not done, the metal will break off when the tool reaches the end of the cut, leaving a ragged edge. The depth of the chamfer depends on the amount of metal to be removed.

Fitting is the term generally applied to the hand work necessary in assembling machinery after all the machine work has been done. Filing, either in the vise or lathe, and scraping are the operations usually required, although the hammer and chisel are sometimes used. As hand work costs much more than machine work, the machining is done as closely as possible to make the hand work a very small item.

SHOP SUGGESTIONS.

In the regular work of any shop, occasions are constantly arising for the determination of the best method of doing work. The success with which the desired end is attained depends upon the skill and judgment of the man in charge. While it is impossible in a limited space to give instructions regarding every possible emergency that may arise, a few suggestions regarding shop practice will be valuable.

Pening consists in the stretching of the metal on one side of a piece of work in order to alter its shape. There is a wide difference between pening and bending. For example, suppose the curved or warped piece in Fig. 199 is to be straightened. If it were to be bent until it were straight, it would be placed on the blocks A with the concave surface down, as shown by the dotted lines. It could then be struck by the hammer and driven down past the line of support, and strained so that it would remain approximately straight. Such a method of straightening

could not be applied to a piece of complicated outlines. It would remain wavy. In pening to truth such a piece as shown in Fig. 199, it is laid on an anvil with the convex surface down. It is then struck with the pene of the hammer on the concave side. The blow must be quick and sharp. The result is that the metal is stretched at the point where the blow is struck. By working successively over the whole surface the concave side is stretched so that it is equal, in its dimensions, to the convex side. The piece then becomes straight and will so remain. A skillful use of the hammer will straighten almost any warped piece of thin metal.

Drilling Hard Metals. It is sometimes desirable to drill a hole in very hard metal. To do this the drill must be made very hard; it must be run at a very slow speed; it must be forced against the work as hard as possible without breaking the point, and it must be provided with an abundant supply of oil. For excessive hardening of a drill, it may be heated to a dull red heat, preferably in a charcoal fire, and quenched in mercury instead of water. It will also assist in the operation if the surface of the metal to be drilled is nicked with a cold chisel before work is begun. In some cases turpentine, in place of oil, may be used with beneficial results.

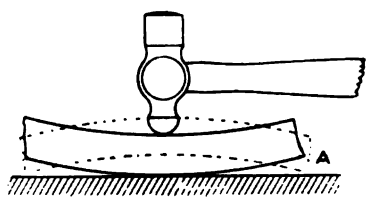


Fig. 199.

Thin chilled cast iron may be softened by placing a small piece of sulphur on the place where a hole is desired and then heating slowly to a dull red.

Glass may also be drilled. There are two methods: one is to use a flat drill moistened with camphor and turpentine, and the other is to use a copper tube with No. 60 emery or carborundum and oil. In the last method, drill half-way through, reverse, and drill to meet, removing the fin at the center with a round file wet with water or turpentine.

Grinding Valves. This is a kind of grinding that is usually done by hand. It consists of fitting a valve and its seat so that they are in metallic contact. In its results it is the same as

scraping. The process is very simple. The valve is coated with oil and some fine emery sprinkled over it. It is then put on the seat and worked back and forth or revolved. The emery serves to grind off the high surfaces of each. After grinding for a time, remove the valve and wipe both surfaces clean. The metal on each will show where they have been in contact. When these indications appear over the whole of the surface, or in a continuous ring about the seat of a circular valve, the work is completed.

To generate a surface plate it is necessary to work with three at the same time. For the sake of making the explanation clear they will be called A, B, and C. After the plates have been planed, a straight edge should be laid on each. A straight edge is merely a piece of flat steel having one or both edges true and straight. Set the straight edge on the plates in all directions. If it touches over its whole length in all positions, then the plates are ready for scraping. If it touches at the edges of the plate and is clear in the center, the former are high and should be filed down. If it touches in the center and rocks to and fro, the plate is convex and the center must be filed down. After the plates have been filed to truth as far as truth can be indicated by the straight edge, they are ready for scraping.

Now take plates A and B and place them face to face. Strike a blow on the upper one, and it will cause a jarring sound to be heard. This shows that the two are not in perfect contact. Smear the surface of plate A with a thin mixture of red lead and oil. Cover the surface evenly and thinly. Then rub the two plates together, and where the red lead rubs off on to the surface of plate B the two come in contact. Take the scraper and scrape off a little of the metal from each of the plates where they have been in contact. Wipe off plate B, and again smearing plate A, proceed as before. Continue this process until the two surfaces are in contact over their whole areas. This does not prove, however, that they are flat. They may be in contact, as required, if A is convex and B is concave. To test this the third plate is necessary. Smear plate B with red lead and scrape C to fit it. Do not touch A. It is evident that A and C will then be alike. Bring them together. If they are both convex they will roll over each other. If they are concave they will bear at their edges and

not touch in the center. They will appear to be out of truth by twice the actual amount. Scrape off the contact points of A and C. Remove as nearly as possible the same amount of metal from each. When these two plates have been brought so as to be in contact over their whole areas, lay plate A aside and scrape B until it fits C, but do not touch A. Then try A and B together. If they do not touch over their whole areas, treat them as before described for A and C. Then introduce C again. Continue this alternating process until the three plates form a bearing over the whole of the surface of each of the other two.

During the latter part of the process, use alcohol instead of red lead. This will leave clean, bright spots at the points of contact.

Fitting Brasses is a piece of work that is now usually done on a machine, but which is sometimes done by hand. Brasses that are to be used for connecting rods, and which are made in two pieces as shown in Fig. 200, have a tendency to warp after the machine work has been done upon them. The difficulty arises from their closing along the diameter A. Thus if the brass is finished, and the hole bored out to the proper diameter, and is then cut apart on the line CD, it will be found, shortly afterwards, that the diameter A is less than the diameter B. It may, therefore, be necessary to bore the hole somewhat larger than the working diameter. The kerf made by the saw will usually allow the parts to be drawn together along the diameter B so that it will more than make up for the shrinkage at A. The hole can then be scraped to fit the pin. The brasses should always be keyed solidly metal to metal. This avoids a wear of the sides and edges of the metal due to the thrust of the rod.

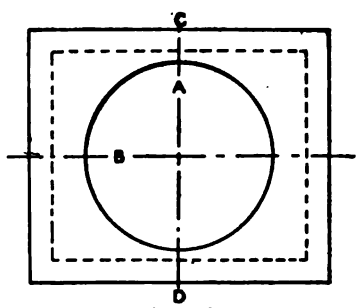


Fig. 200.

Joints. Where a gas or liquid is to be retained in a pipe or other vessel without leakage, a tight joint is necessary. The method of grinding valves to their seats has already been explained. In that case it was shown that a metallic contact

between the valve and its seat is all that is required in order to make it a tight joint. Two surfaces that have been scraped to fit will also accomplish the same purpose. This is frequently too expensive an operation to be performed, especially on rough work. In such places a soft material may be interposed between the two surfaces. Where the joint is to be a permanent one and is not to be taken down, the red lead joint is usually employed. This consists in the use of a mixture of red and white lead between the joints. To ordinary white lead ground in oil add enough dry red lead to make a paste that can be spread without sticking to the blade with which it is applied. After the mixture has been made, it will be improved by pounding it well with the hammer. It may then be laid between the two pieces of metal forming the sides of the joint and the latter be drawn together. Red lead joints are extensively used in pipe fitting. The red lead has a tendency to rust the iron with which it is in contact, and thus form a very tight connection between the two pieces. Where provision is to be made for taking down the joint at a future time, it is better to use a graphite paste made for the purpose. This does not rust the metal; it forms a perfectly tight joint and one which may be taken down without difficulty at any time.

Joints that are subject to occasional disconnecting can be best held by a disk of rubber packing. The latter is cut to fit the flanges between which the joint is to be made, and they are then drawn tightly together.

Joints that are to be frequently taken down are usually packed with a piece of copper wire. Such a place is the joint between the steam chest and cylinder of a locomotive engine. A groove is cut in the two surfaces and a copper wire is laid therein. This wire should be about $\frac{1}{4}$ inch in diameter. Its size, however, depends upon the joint to be packed. The ends of the wire are soldered together so that no leakage may occur past the ends.

Another form of joint is the rust joint. This is always permanent in character. The making of such a joint consists in rusting the two surfaces together. The following are the proportions by weight of the rusting material: 100 parts of iron

turnings; 1 part of sal ammoniac, and ½ part of sulphur. The setting of the joint can be hastened by increasing the amount of sal ammoniac from 15 to 25 per cent. Mix the ingredients thoroughly and just cover them with water.

Fluting Rollers. Where feed rollers such as those used in wood-working machinery are to be turned and fluted, the turning should always be done first. This insures a continuous surface for the cutting tool. Where old rollers are to be re-turned and fluted, the same rule applies. The fluted surface may be turned to size. The lathe tool will break the edge of the ribs away, but when the fluting is done, these edges are again made smooth. The fluting can be done on a planer with a round-nosed tool. The roller should be held on centers and clamped so that each groove may be presented to the tool in succession. A planer center, as illustrated in Fig. 178, affords a convenient method of holding and turning the work.

Scale. Whenever a piece of cast iron is to be turned, the point of the tool should always be made to work beneath the scale. The scale is the hard outer shell that covers all cast iron as it comes from the foundry. It is very hard and brittle. If the edge of the tool is made to work in or against it, that edge will soon be dulled. If it is beneath it, the raising of the chip cracks and removes the scale.

Pickling. Where castings are to be worked, either in the lathe or planer, to dimensions only a little less than that when rough, they should be pickled. This consists in washing them with a solution of sulphuric acid and water. The castings may be either submerged in or swabbed with the solution. The effect of pickling is to cause the scale to drop off in flakes, leaving the metal bare, unprotected and rusty. The casting should then be washed with a sal soda solution. A good solution for this work is to use 1 part of commercial sulphuric acid in 10 parts of water.

Cold Chisels. It is well to use a coarser grade of steel for cold chisels than for lathe or planer tools. A coarse-grained metal is preferable because the continual hammering in use and redressing will gradually modify the granular structure until it is microscopic in its fineness. In dressing, it should never be heated above a cherry red, and the temper should be drawn well down

so that the soft metal backs up the edge. A capacity to receive a multitude of grindings is not what is wanted. The tool must be able to endure the severe service for which it is intended. It must cut into a distorted mass of metal, where every blow gives it a shock tending to form a new arrangement of its particles. It never receives the steady pressure of the lathe tool, hence its powers of endurance must be greater.

Lining Shafting. In equipping a shop, the first work of the machinist is the erection of the shafting. The main line should be the first laid out, and the engine, together with the jack and countershafting, must be located from it. After placing the hangers as nearly as possible in a horizontal line, the shafting should be placed in the boxes and attached to the hangers. For

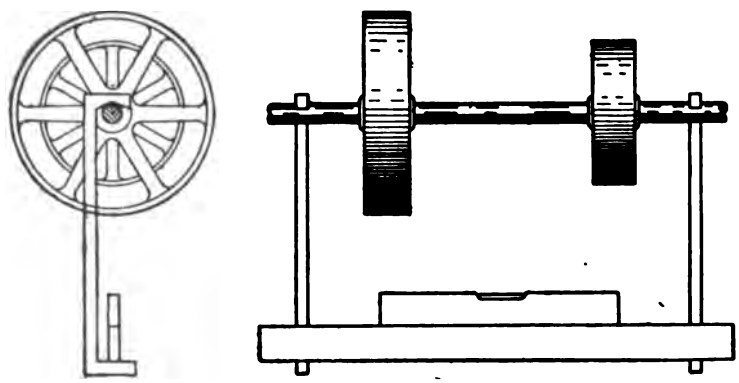


Fig. 201.

lining the shaft, a level and a fine grass or silk line are indispensable. The line is tightly drawn, horizontally, a short distance from the position it is desired that the shaft shall occupy, and the distance from the surface of the shaft to the line is measured and made equal near each hanger by a stick such as is shown in Fig. 202.

The level is used to make the shaft horizontal, and, if the hangers are adjustable in two planes, the operation is quite rapid.

When other shafting is to be erected parallel to the first, if the distance does not exceed twelve or fifteen feet, a long stick such as shown in Fig. 202 may be used by driving a nail into the

end of the stick to allow some adjustment. The level is used as before.

When the distance is great, or obstacles prevent the use of the stick as suggested, a line may be drawn on the floor of the shop by dropping a plumb line from near the ends of the first shaft and connecting the points located. Another line, directly under the desired location, may be drawn by direct measurement, and the second shaft erected by dropping a plumb line to this second floor line near the ends of the second shaft. This method may be employed, with such variations as the case may demand, even though a floor or wall be between the locations.

In leveling up long lines, or around machines, or through walls, the hydrostatic level is a most convenient tool. It consists of two graduated glass tubes set in suitable bases and connected by a rubber tube. When the rubber tube is filled with water, and the glass tubes placed vertically on the shaft, the fluid should stand at the same gradation in each glass. These levels are made with self-acting valves to prevent the escape of the fluid.

When pulleys or hangers make the direct application of a level to the shaft impracticable, leveling hooks, in connection

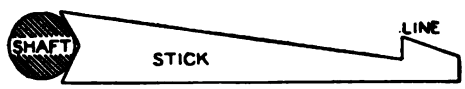


Fig. 202.

with a wooden straight-edge, as shown in Fig. 201, are very convenient. These may be made of wood or metal, and of lengths suitable to the case in hand.

Machine Setting. After the shafting is erected, comes the setting of machines. The countershafts are first erected parallel to the main line, and with due regard to the location of the machine. The machine is then placed with its driving shaft parallel to the counter by use of the plumb line, and the platen, table, or other horizontal surface carefully leveled, in two planes, by wedging up the machine with common shingles. It is then secured to the floor by lag screws.

When the machines are very heavy, and stone or masonry foundations necessary, anchor bolts are built into the foundation at suitable points or holes drilled for expansion bolts. The

machine is then lined and leveled as already suggested, but the bottom of the machine is usually a rough casting, the top of the stone foundation is still rougher, and as the wedges are likely to slip out under the jarring of the machine, a permanent support must be provided. This may be done by pouring melted sulphur beneath the bed. To do this, build a dam of clay or sand all around the bed and about 2 inches high. Melt ordinary stick sulphur or brimstone in ladles, and pour in at several points at once. Keep the space flooded until the dam is well filled, and allow it to harden. This will occur very quickly, after which the dam may be removed and the sulphur cut away from the edge of the machine. Care must be taken that the temperature of the sulphur is as high as possible before pouring. Unless this is done it will cool and set before reaching the inmost recesses beneath the machine. It will then crumble because of insufficient bearing surface to carry the imposed weight. The nuts are then screwed down on the bolts and the machine is secure.

Belting. The shafting and machines are usually driven by belting, and a few remarks on this subject may be desirable. Leather is the material generally employed, and the belting may be from single to six-ply in any suitable width. Single belting has a flesh and a grain or hair side, and should be run with the grain side in contact with the pulley. The ends are cut square, and fastened by hooks, coiled wire, or rawhide lacing.

Leather belting is injured by water, steam, oil, and temperature above 110° F. Where such conditions exist, cotton belts, faced with thin leather, or rubber belts may be used. These belts are cheaper than leather, are about as strong, and will transmit power as effectually; but they will not stand mutilation of the edges. This is a point of prime importance, and prohibits their use in many cases.

The power transmitted by a belt is directly proportional to its speed and width. A safe rule is to allow one horse-power for a speed of 1,000 feet per minute, with a single-thick belt one inch wide. This is a more liberal allowance in favor of the belt than is usually given, but will increase the life of the belt in far greater proportion than the increase in first cost. Double belts will transmit about one and one-half times as much power as single

belts. The above rule applies to belts running over pulleys of equal diameter, or, in other words, to cases where the arc of contact is 180°. For smaller arcs of contact use the coefficients found in the following table:

90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	200°
.65	.70	.75	.79	.83	.87	.91	.94	.97	1.	1.05

To increase the power transmitted, either increase the speed of the belt by using larger pulleys, or use a wider belt.

A 3-inch single belt is running over a 24-inch driving pulley which makes 200 R.P.M. (revolutions per minute). How many H.P. will it transmit?

The circumference of the pulley in feet is $2 \times 3.1416 = 6.2832$ feet. As the speed of the pulley is 200 R.P.M., the speed of the belt will be $200 \times 6.2832 = 1256.64$ feet per minute. For every inch of width it will transmit $1256.64 \div 1000 = 1.25664$ H.P. Then a 3-inch belt will transmit $3 \times 1.25664 = 3.76992$ H.P. *Ans.* 3.75 H.P. (approx.).

It is desired to increase the H.P. in the above example to 5 H.P. How may it be done?

(1). By using a wider belt in the proportion of 3.75 to 5. 3.75 : 5 : : 3 : 4. *Ans.* By using a 4-inch belt.

(2). By using a larger pulley in the same proportion. 3.75 : 5 : : 24 : 32. *Ans.* By using a 32-inch pulley.

(3). By using a double belt. 1 : 1.5 : : 3.75 : 5.63. This would give a little better result than required.

Interior of main machine shop of the Fore River Ship and Engine Company, showing on the left a 114-foot boring lathe.

SECTION 5.

TOOL MAKING.

As generally understood, a tool maker is a machinist who has a greater knowledge of the trade than is simply sufficient to enable him to make such machines or parts of machines, as may be the regular product of the shop in which he may be employed.

The business of the tool maker is to make the tools for producing the different parts of the machine, implement or apparatus, and relates not only to cutting tools, but to jigs and fixtures for holding the work while the various operations are being done, and making the necessary gauges to determine when the different parts are of the correct size and shape. Also the making of the models for the different fixtures and gauges. In some shops where there is work enough of the two latter described classes, the tool makers regularly employed on this work are termed gauge makers and model makers respectively. Yet in the average shop the models and gauges and such special machinery as may be required are made by the tool maker.

In order to acquire any degree of success, the tool maker must not only be able to work accurately and within reasonable time, but he must have a knowledge of drafting to enable him to read quickly and accurately any ordinary drawings. Unless he can read decimal fractions readily and accurately, he will experience much difficulty when working to measurements that require accuracy within one ten thousandth part of an inch. As most of the measuring instruments used by the tool maker read to one thousandth part of an inch, and some of them to the ten thousandth part of an inch, or even closer, it will be readily seen that in laying off measurements for gauges, models, drill-jigs and similar work, a thorough knowledge of Arithmetic is essential.

A tool maker should be familiar with the accurate reading of the micrometer and of the vernier as applied to the vernier cali-

per, vernier depth gauge and vernier height guage. He must bear in mind when using the vernier caliper for inside measurements that it is necessary to add the amount of space occupied by the caliper points A A Fig. 1 to the apparent reading on the vernier side.

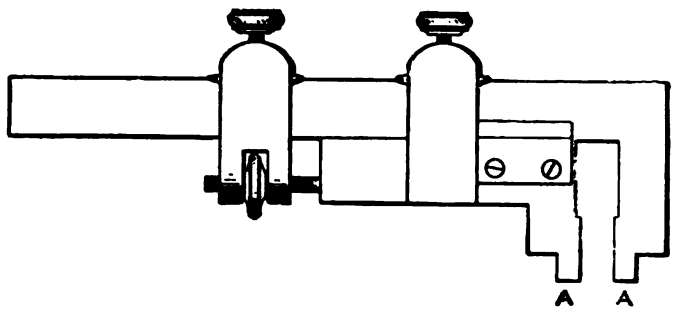


Fig. 1.

When measuring the distance between the centers of two holes as in Fig. 2, the vernier may be set so that the portions of the jaw marked A A Fig. 1 will exactly caliper the distance from B to B′ in Fig. 2. To the apparent reading of the vernier add the space occupied by the caliper points, and from this subtract one-half the diameter of each of the holes. It is necessary to

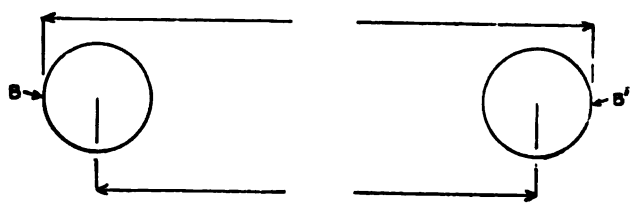


Fig. 2.

caliper the size of *each hole*. Do not take anything for granted when accurate measurements are necessary. A reamer *should always* cut an exact size, but experience proves that it does not always do so. If the size of the hole is taken for granted, a variation of .002 inch means an error of .001 inch in a measurement.

While extreme care should be exercised where accuracy is essential, there are parts of a tool where *approximate* measurements will do. If within $\frac{1}{16}$ inch is sufficiently accurate, it is folly to spend time to get a dimension within a limit of one ten thousandth part of an inch.

Approximate measurements are those made with the aid of calipers, dividers, surface guage, etc., set to an ordinary steel rule. Precise measurements are obtained by the aid of the various measuring instruments graduated to read to very small fractions of an inch. Also by the use of standard reference discs, and standard test bars, accurate within a limit of variation of $\frac{1}{50000}$ part of an inch. In using the micrometer, vernier or any of the measuring

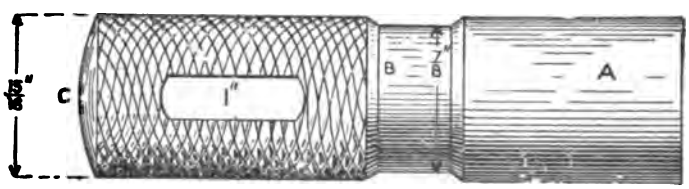


Fig. 3.

instruments supposed to give accurate readings, it is necessary to exercise great care in setting the tools. In setting the vernier it is well to use a powerful eye-glass in order that any error in setting may be so magnified as to be readily apparent.

The difference between the two characters of measurements described — approximate and precise — may be readily seen in the plug gauge shown in Fig. 3. The gauge end A must be, when ground and lapped, *exactly* 1 inch in diameter, as shown by the stamped size on the handle C. The handle should be $\frac{15}{16}$ inch in diameter and knurled, and the neck $\frac{7}{8}$ inch. While the end marked A is necessarily a *precise* measurement, B and C are approximate, and an error of $\frac{1}{64}$ inch or more on either diameter would not interfere with the accuracy of the gauge. This does not mean that so great an amount of variation from given sizes should ever occur, but the illustration is given to show that the practical workman will never spend an unnecessary amount of

time to produce accurate measurements when approximate measurements will do. On the other hand, all care possible should be taken when lapping the gauge end A to size.

Points to be Observed. Keep the working parts of any machine you may be running as clean as possible. Do not allow chips to collect on the shears (Vs) of your lathe. If these become roughed or worn, accurate turning cannot be done. Keep the machine thoroughly oiled, clean the oil holes out occasionally with a piece of wire, in order that the oil may get to the bearings.

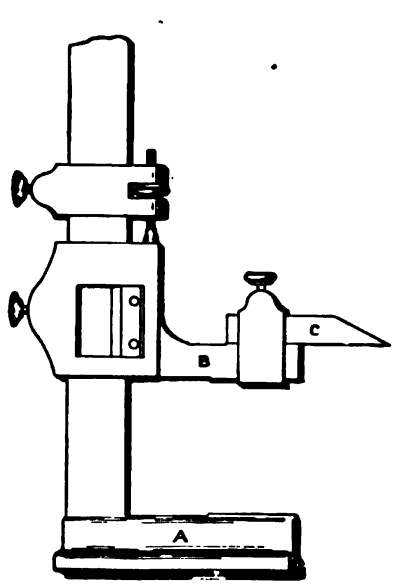


Fig. 4.

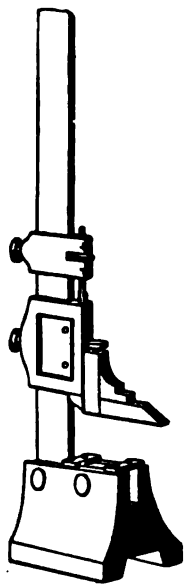


Fig. 5.

Keep the centers of your lathe in good condition, have them to gauge, and be sure the live center runs *true* before taking any finishing cuts. Try the center gauge on your countersink occasionally to see that it maintains its correct shape. Keep your center punch ground to a good point. It is advisable to grind the prick punch used in locating working points in some form of grinder having a chuck or collet to hold the punch while revolving it against the emery wheel; if the point is not perfectly round it will be impossible to indicate a piece of work perfectly on the faceplate of the lathe by means of the center indicator.

Special Tools. A vernier height gauge (Fig. 4) is a very handy tool for making drill jigs, templets and other tools requiring very accurate measurements, and for locating working points, holes or drill bushings. It is used for obtaining the height of projections from a plane surface, or the location of bushings in drill jigs, etc. The fixed jaw A is of sufficient thickness to allow the gauge to stand upright. An extension C attached to the movable jaw B can be used for scribing lines when laying off measurements. In the absence of a height gauge the regular vernier caliper may be made to answer the same purpose by making a base, which may be attached to the fixed jaw as shown in Fig. 5.

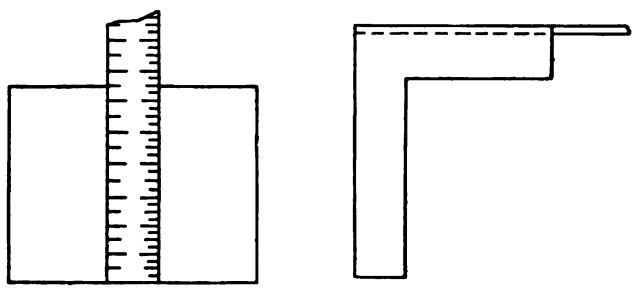


Fig. 6.

A small angle iron having a slot in the upright face to receive a scale for use in connection with a surface gauge when laying off measurements is shown in Fig. 6. The slot should be planed perfectly square with the base of the angle iron.

A pair of accurately machined V blocks is a necessary part of every tool maker's kit. If made of machinery or tool steel they will not need truing as often as if made of cast iron. After roughing out the V's, every surface should be planed square. They should be then clamped against the rail on the planer table by means of finger pieces, having previously trued the edge of the rail. The head of the planer should then be set to the proper angle, usually 45°, and one of the angles finished; the head may now be set over the opposite way and the other angle face planed. The tool used should be ground to give a smooth cut, as it is not advisable to do any finishing with a file or scraper.

A few small gauges of the most common angles will be found very convenient, as they can be used in places not accessible with the ordinary bevel protractor; the angles most commonly used are 60°, 65°, 70° and 80°. The form of gauge is shown in Fig. 7.

If the tool maker should be called on to make punch-press dies, one or more angle gauges, as shown in Fig. 8, will be found very useful. Many die makers use an adjustable square having a narrow blade which passes through the aperture in the die. The amount of clearance given is determined by the judgment of the workman; while this method does very well when practiced by an experienced man, it is rather uncertain when attempted by the novice. To get the proper clearance, the beginner should use the gauge shown in Fig. 8, called (improperly) a die maker's square.

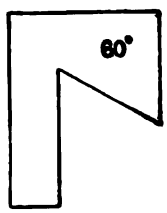


Fig. 7.

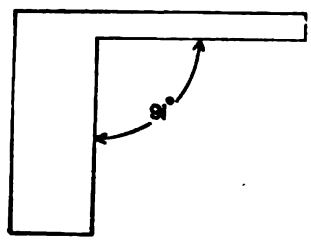


Fig. 8.

The angle depends on the nature of the stock, and the custom in the individual shop; but a set of three gauges, one 91°, one 91½°, and one 92° will meet the requirements, as the clearance is seldom less than 1° or more than 2°. The angle should be stamped on the wide part of the gauge, as shown in Fig. 7. To avoid springing out of shape the stamping should be done before the gauge is finish-filed at any point.

The tool maker should always have at hand a solution of blue vitriol for coloring the surface on which he is to draw lines. To make the solution, dissolve in a two-ounce bottle of water all the blue vitriol crystals the water will take up; to this add one-half teaspoonful of sulphuric acid. This produces a copper-colored surface when put on polished steel free from grease and dirt.

STEEL.

Tool steel is used for tools intended for cutting, pressing, or working metals or other hard materials to shape. In order to successfully work tool steel a knowledge of some of its peculiarities is necessary.

Carbon is the element in tool steel that makes it possible to harden it by heating to a red heat and plunging into a cooling bath. A bar of steel from the rolling mill or forge shop is decarbonized on its outer surface to a considerable depth; consequently this portion will not harden, or if it does the results will be far from satisfactory. For this reason if a tool is to be made having cutting teeth on its outer surface, it is necessary to select stock of somewhat greater diameter than the finish size, so that this decarbonized portion may be removed. About $\frac{1}{16}$ inch for sizes up to $\frac{1}{2}$ inch, $\frac{1}{8}$ inch for sizes up to $1\frac{1}{2}$ inches, $\frac{3}{16}$ inch for sizes up to 2 inches, and $\frac{1}{4}$ inch for sizes above 2 inches will usually be sufficient.

Tool steel may be procured in almost any form or quality. It is ordinarily furnished in round, octagonal, square or flat bars. Many tool makers prefer octagonal steel for tools which are to be circular in shape, but experience shows that steel of various shapes of the same make does not differ materially provided the quality and temper are the same.

Cutting tools should be made of high carbon steel if it is to be forged or hardened by skillful operators. If the steel is to be heated by an inexperienced man, it is not safe to select a steel having a high percentage of carbon.

For non-cutting tools, such as mandrels, it is well to select a low carbon steel (one per cent carbon or less), because with this steel there is not as great a tendency to spring when hardening.

Hammered steel is prized more highly than rolled steel by fine tool makers, but authorities do not agree on this point. It is generally conceded, however, that the best tools can be made from forgings if the heating and hammering have been correctly done. The steel should be heated uniformly throughout, and hammered carefully with heavy blows at first. Lighter blows should follow, and, when the piece passes from low red to black, great care is needed to prevent crushing the grain. Steel properly heated and hammered will have a close, fine grain.

Cutting from Bar. It is advisable when cutting a piece of stock from the bar to use a *cutting tool* of some description, such as a saw or cutting-off tool. It is decidedly poor practice to weaken the bar with a cold chisel and then break by a sudden blow or yank. This process so disarranges the particles of steel that they do not assume their proper relations with one another when hardened. If it is necessary to cut the steel with a chisel heat the bar to a *red heat*, as it may then be cut off without injury.

Centering. When centering, care should be taken that the center punch mark is exactly in the center of the piece on each end, so that an equal amount of the decarbonized material will be turned from all parts of the piece (see Fig. 9.) If centered as shown in Fig. 10 the decarbonized portion will be entirely removed

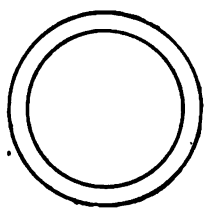


Fig. 9.

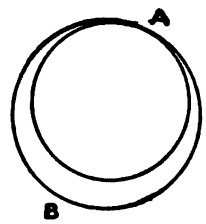


Fig. 10.

at side marked B, and will not be on the side marked A, consequently when the piece is hardened the side marked B will be hard, while the opposite side A will be soft, or at least not as hard as B.

Straightening. A piece of tool steel that is to be hardened should *never* be straightened when cold. If it is bent too much to remove all the decarbonized steel when turning to size, it is best (generally speaking) to use a straighter piece of stock. But if the bent piece must be used, heat it to a red heat and straighten. A piece of steel straightened when cold is almost sure to spring when hardened.

ANNEALING.

In order that it may be soft enough to work easily, tool steel must be annealed. It can generally be bought in this condition cheaper than it can be annealed when needed in the factory. An-

nealing also removes the strains, or the tendency of the steel to crack and spring when hardened. Strains are caused by rolling and hammering in the steel mill or forge shop. In order to remove this tendency to spring, the piece of steel should be machined somewhere near to size, yet leaving sufficient stock to machine all over after the annealing. If it is a piece with a hole in it, such as a milling machine cutter blank, the hole should be drilled somewhat smaller than finish size ($\frac{1}{16}$ inch is the amount generally allowed) and the piece turned in a lathe to remove all the outer surface which contains the marks of the hammer or rolls. The piece is now ready for annealing. To anneal a piece of steel it should be heated to a uniform red heat and allowed to cool slowly. Steel may be annealed by any one of several methods.

Box Annealing. For this method it is necessary to have a furnace large enough to hold an iron box of sufficient size to take the piece to be annealed. To do this work cheaply, enough pieces should be annealed at a time to fill one or more boxes, according to the capacity of the furnace.

The material used in packing the box is wood charcoal, which should be ground or pounded until the particles are about the size of a pea. A layer of charcoal covering the bottom to a depth of one inch is first placed in the box, then a layer of steel. The different pieces should not come within $\frac{1}{2}$ inch of each other nor within 1 inch of the box at any point. The spaces between the pieces are filled with the charcoal, and they are covered to a depth of 1 inch. Another layer of steel may be put in if the box is of sufficient size. When within $1\frac{1}{2}$ inches of the top fill with charcoal, tamp down, put on the cover, and lute around the edges with fire-clay, to prevent the direct heat of the fire entering the box.

Test Wires. There should be several $\frac{1}{4}$-inch holes drilled through the cover near the center, and through each of these a piece of $\frac{3}{16}$ inch wire should be placed. The wires should extend to the bottom of the box and project about 1 inch above the top of the cover in order to be readily grasped by the tongs. These wires are intended to be drawn from the box in order to determine when the contents are red hot. The box should be placed in the furnace. After the box has become thoroughly heated, one of the wires may be drawn out by means of a pair of long tongs. If no

such tongs are available the legs of ordinary tongs may be lengthened by pieces of gas pipe. Note the time when the wire is red hot the entire length. If not red hot draw another in ten or fifteen minutes, and continue doing so until a wire is drawn that is red the entire length. The work should be timed from the time the box is heated through; this is shown by the wire.

The heat should be maintained a sufficient length of time to insure a uniform heat, which should not be allowed to go above a full red. The length of time the pieces remain in the fire depends somewhat on the size; for steel 2 inches and under, one hour after the box is heated through will do; larger pieces require a longer time. After running for the necessary length of time the heat should be shut off and the boxes allowed to cool slowly; the pieces should be left in the box until cold.

When there are no facilities for annealing by the method described, the piece may be heated to a uniform red and placed on a piece of board in an iron box, having one or two inches of ashes under the board. A second piece of board should be placed on the steel and the box filled with ashes. The pieces of wood will smoulder and keep the steel hot for a long time.

Another common method of annealing tool steel is to heat the piece to a red heat and bury it in ashes or lime. This is likely to give unsatisfactory results unless the ashes or lime are also heated. This can be accomplished by first heating a large piece of iron and burying in the contents of the annealing box. When the steel to be annealed is sufficiently heated the piece of iron may be removed and the piece to be annealed put in its place and thoroughly buried in order that it may take a long time in cooling; it should be allowed to remain in the ashes or lime until cold.

There is another method of annealing practiced in some shops, which answers in an emergency, but it is not to be recommended for general use. This is known as the *water anneal.* The piece of steel should be heated to a *low red,* making sure that the heat is uniform throughout. It should be removed from the fire and held in the air where no draft can strike it until no trace of red can be seen, even if the piece is held in a dark place; it should then be plunged in water, and allowed to remain until cold. Better results may be obtained if plunged in soapy water or oil.

Long pieces which spring when annealed should not be straightened when cold, if they are to be hardened.

HARDENING.

Tool steel may be hardened by heating to a low red heat and plunging in some cooling medium, as water, brine or oil.

Heating. A piece of steel should never be heated any hotter than is necessary to give the desired result. The heat necessary varies with the make of the steel, the amount of carbon it contains, the size and shape of the piece, and the purpose for which it is to be used. Much depends on heating uniformly; a piece of steel should be given a *uniform heat throughout*, the edges and corners should be no hotter than the center, and the interior should be of the same temperature as the surface. If not, the piece is likely to crack in the cooling bath, on account of the uneven changes which take place in the molecular structure. While it is highly important that the steel is heated no hotter than is necessary, yet it is of *much more* importance that it be heated uniformly.

If the piece is heated in an ordinary forge, be sure that the air from the blast does not strike it. For a large piece build a large high fire; have it well heated through before putting in the steel. Use the blast only enough to keep a lively fire; have the steel well buried in the fire in order that the air may not strike it.

Cooling. When the piece is uniformly heated it should be plunged into a suitable bath to give it the proper hardness. It must be worked rapidly up and down, or around in the bath in order to get it away from the steam generated by the red hot steel coming in contact with the liquid, and also that it may constantly come in contact with the cooler parts of the bath. If the piece is long and slender it must be worked up and down; if it is short with teeth on the outer edge, as a milling machine cutter, it should be worked around rapidly in order that all the teeth may be cooled uniformly. If it is flat and has a hole through it whose inner walls must be hard, it should be swung back and forth in order that the bath may pass through the aperture and at the same time strike both faces.

If the tool is not to be hardened all over, and it is necessary

to heat it higher than the point where the hardening is to stop, it may be dipped in the bath to a point a trifle higher than we wish it to harden, and then worked up and down a little. If this is not done there will be a line where the piece is expanded at one side and contracted on the other; it is likely to crack at this line, which is called a "water line."

Delicate articles, or those tools having long projections or teeth, should not be dipped in a bath of very cold water or brine; for such work a tepid bath gives better results.

Steel should always be hardened at a heat that leaves the grain *fine* when the piece is broken. This can be determined by hardening and breaking a small piece from the same bar from which the tool to be is made. A *coarse grain* denotes a heat higher than the steel should receive.

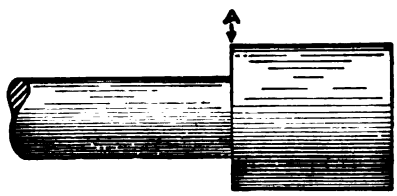


Fig. 11.

It will be found necessary when heating some kinds of steel to put the articles in an iron tube so that air cannot come in contact with them; this is especially true when hardening such tools as taps or formed mills whose outer surfaces cannot be ground, because the oxygen in the air acting on the carbon at the surface of the piece of steel *burns* it, leaving the surface decarbonized. Better results can be obtained with any tool if it is kept from the action of the fire when heating for hardening.

When hardening a piece having a shoulder A, on the outside, as shown in Fig. 11, or inside, as shown in Fig. 12, hardening should not stop at the shoulder, as the unequal strains occasioned by the contraction of the hardened part at the shoulder are likely to cause it to crack at that point. The piece should not be hardened as high as the shoulder, but should it be necessary to do so, it is well to harden a little beyond.

Citric Acid Bath. An excellent bath for hardening small pieces may be made by dissolving one pound of citric acid crystals in one gallon of water. It should be kept tightly closed when not in use or it will evaporate. Small tools heated to a low

red heat and dipped in this solution harden more uniformly than when immersed in clear water.

Pack Hardening gives excellent results with pieces that cannot be hardened by the methods ordinarily employed without risk of springing or cracking. The article is packed in an iron box with some carbonaceous material, and subjected to the action of heat to allow it to absorb enough carbon to harden in oil. While this method is not generally used, it is very valuable when hardening such pieces as milling machine cutters, blanking dies for punching presses, gauges, and taps where it is necessary that the diameter and pitch are not altered. The carbonaceous material is charred leather, which should be ground or pounded very fine (usually about one-half the size of a pea), and mixed with an equal quantity (volume) of wood charcoal whose granules are of about the same size. These should be thoroughly mixed. An iron box somewhat larger each way than the piece to be hardened should be selected. A layer of the packing material one inch deep should be placed in the bottom of the box and the piece laid on this; the box should then be filled with the packing material and tamped down. Fill the space between the cover and the box with fire clay, thus sealing it so that the gases in the box cannot escape and the direct heat of the fire cannot get into the box.

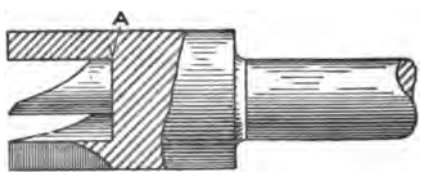


Fig. 12.

It is much more economical to pack a number of pieces at a time, as several may be hardened at the cost of one, and at a saving in packing material. The pieces should be wired with ordinary iron binding wire of a sufficient size to sustain the weight when the wire is red hot. One end of the wire should project over the outside edge of the box, and should be covered with the luting of fire clay. Several holes should be drilled near the center of the cover for test wires, as when annealing. The wires should extend to the bottom of the box. The box may now be heated sufficiently to charge the pieces with carbon. As steel does not commence to absorb carbon until it is red hot, the time is

determined by means of the test wires as described under "Annealing." For ordinary tools ½ inch diameter and under, run 1 hour to 1½ hours after it is red hot; pieces from ½ inch to 1 inch diameter, 2 to 2½ hours; pieces from 2 to 3 inches diameter, 2½ to 4 hours. The above must be varied according to the nature of the work.

After remaining in the furnace, the box should be taken out, the cover removed, and the piece taken out by means of the wire attached to it. It should then be immersed in a bath of *raw linseed oil.* The piece should be worked around in the bath until the red has disappeared; it may be then lowered to the bottom of the bath and allowed to remain until cold.

When a piece of steel one inch in diameter or larger is hardened, it should be reheated over the fire immediately on taking out of the bath, in order to avoid cracking, from the strains caused by molecular changes which take place after the outside surface is hardened and unable to yield to the internal strains. Reheating the surface to a temperature of about 212° will accomplish the desired result without materially softening the steel.

TEMPERING.

The hardening of a cutting tool makes it too brittle to stand up well when in use, and consequently it is necessary to soften it somewhat. This is known as "drawing the temper," and is accomplished by reheating to the proper temperature, which is ordinarily determined by the color of the surface of the tool, which must be brightened previous to this operation. As the piece of steel is heated, a light, delicate straw color will appear; then, in order, a deep straw, light brown, darker brown, light purple, dark purple, dark blue, pale blue, blue tinged with green, black. When black, the temper is gone. These colors furnish a guide to the condition of hardened steel.

The following list gives the color denoting the tempers generally used for tools:

Light straw	For lathe and planer tools, scrapers for brass, etc.
Deep straw	For milling cutters, reamers, large taps, etc.
Brown	For twist drills, drifts, flat drills for brass, etc.
Light purple	For augurs, screw slotting saws, etc.
Dark purple	For saws for wood, cold chisels, screwdrivers, etc.

The following table gives the degree of heat corresponding to the different colors mentioned in the previous table.

Light straw	430 degrees F.
Deep straw	460 degrees F.
Brown	500 degrees F.
Light purple	530 degrees F.
Dark purple	550 degrees F.
Dark blue	570 degrees F.
Pale blue	610 degrees F.
Blue tinged with green	630 degrees F.

When work is tempered in large quantities the above method is expensive. Also it is not as reliable as when the articles are heated in a kettle of oil, using a thermometer for indicating the temperature. A piece of perforated sheet metal or wire cloth should be used to keep the articles two or three inches from the bottom of the kettle. A perforated sheet iron pail two inches smaller in diameter than the kettle, resting on a piece of iron, or a frame placed in the bottom will keep the pieces from the sides and bottom of the kettle.

The thermometer should be placed in the kettle outside the pail in order that the bulb may be at the same depth as the lower pieces.

Case Hardening. When an article of wrought iron or machinery steel is to have a hard surface it is treated while red hot with some material which forms a coating or case of steel, which hardens if dipped in water while red hot. Small articles such as nuts, screws, etc., may be case hardened by heating red hot and covering with a thin layer of powdered cyanide of potassium; when the cyanide of potassium melts, the article may be heated red hot again; it is then plunged into water. Care should be exercised when using this substance, as it is *extremely poisonous.*

The above method may be used for hardening a few pieces quickly, but it is not recommended for large quantities of work. When many pieces are to be case hardened at a time, the following method will be found less expensive and much more satisfactory:

Granulated raw bone and granulated charcoal should be mixed in equal quantities, and a layer of this mixture placed in

an iron hardening-box to the depth of 1 or 1½ inches. A layer of articles is then placed on this; the pieces should not come within ½ inch of each other, nor within 1 inch of the walls of the box at any point; they should be covered with a layer of the mixture of bone and charcoal to the depth of ½ inch. Successive layers may be placed in the box until it is filled to within 1 inch of the top, when the cover may be put in place and the edges luted with fire clay. The test wires should be used as described for annealing. The heating should be timed from the time the contents of the box are red hot, which can be determined by the test wires. The length of time the work is allowed to run while red hot depends upon the desired depth of the hardened surface; generally carbon will penetrate wrought iron ⅛ inch in twenty-four hours, but as it is rarely necessary to harden deeper than 1/32 inch, the work may be kept red hot three to four hours. With small pieces, the contents of the hardening-box may be dumped into a tank of running water; if the pieces are large, it is necessary to dip them one at a time in a bath, the same as for tool steel. For extreme toughness, the pieces, if small, may be dumped into a perforated sheet-metal pan and the *packing material sifted out*, after which they may be placed in a bath of oil; if not sifted out, the packing material will stay at the top of the oil and set fire to it. If the pieces are large, they may be dipped one at a time.

Spring Tempering. A piece of steel may be spring tempered by first hardening and then drawing the temper to a degree to which the piece, when bent, will return to its normal shape, when the pressure is removed. This may be accomplished by covering the surface with tallow or some animal oil, and then heating until the oil catches fire from the heat in the piece.

DRILLS.

The forms of drills commonly used in the machine shop are the flat drill, single-lip drill and twist drill.

Flat Drills, intended for use in the engine lathe for chucking, are usually forged to shape in the forge shop. After centering the end, which rests on the tail center of the lathe, the lips are ground to shape and the drill is ready for use. A drill of this description is shown in Fig. 13.

If it is necessary to have the drill cut nearly exact to size, it should be forged somewhat wider than finish size, and the edges turned in the lathe as in Fig. 14. The projection A must be left on the cutting end to provide a center for turning. If the drill is to be ground to size after hardening, the projection must be left on until the grinding has been done, but, ordinarily, this class of drill is not intended to cut exact enough to require grinding.

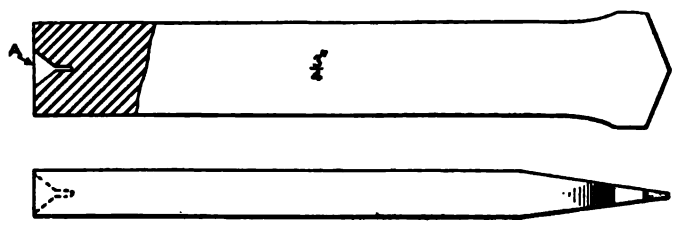


Fig. 13.

If the edges of the drill are not to be ground to size, they should be draw-filed a small amount to avoid binding. The filing should not come within $\frac{1}{64}$ inch of the edge, and should be only a small amount (.003 or .004 inch will be found sufficient); if given too much relief the drill will jump and chatter. The shank should be somewhat smaller ($\frac{1}{32}$ to $\frac{1}{16}$ inch) than the cutting end

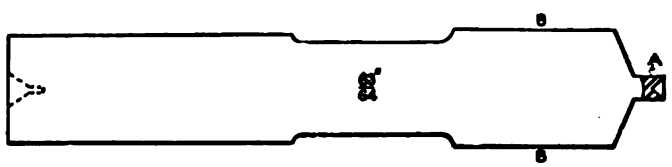


Fig. 14.

in order not to touch the sides of a hole drilled deep enough for the shank to enter. The center in the shank end should be large, to insure a good bearing on the tail center of the lathe, as shown at A, Fig. 13.

When hardening, the drill should be heated a *low red* to a point above the cutting end, preferably about one-half the length

of the portion turned smaller than the ends. When dipped in the bath it should be plunged about one inch above the cutting end. To insure good results it should be worked up and down and around in the bath, which may be either water or brine. The temper should be drawn to a brown color.

When a flat drill is intended for use in a drill press, the shank is left round, in order that it may be held in a chuck or collet.

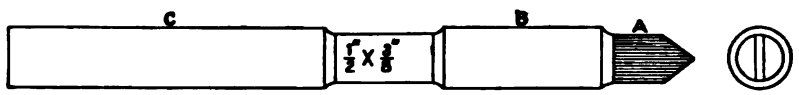


Fig. 15.

Transfer Drill. Another form of flat drill termed a transfer drill, is very useful when a small hole is to be transferred from a larger. The shank C, Fig. 15, may be made of any convenient size; the portion B is of the size of the larger hole, while A is of the size of the hole to be transferred, and is a short *flat* drill.

When making this drill, if a lathe is used having draw-in split chucks, the drill may be made from drill rod, which should be enough larger than finish size to allow B to be turned, to insure its running true with A; the cutting part A may be milled or

Fig. 16.

filed to thickness. The cutting lips are then backed off, and the drill hardened. It should be hardened high enough so that A and B are hard, as the portion A does the cutting, while B, being a running fit in a hole, is likely to rough if it is soft.

To harden it should be heated in a tube and dipped in water or brine, and worked up and down, to avoid soft spots caused by steam keeping the water from the metal, as sometimes happens when a piece has different sizes close together. The cutting portion A should be drawn to a deep straw color; B should be left as hard as possible, to resist wear.

Straightway, or straight fluted drills, have the flutes cut parallel to a plane passing through the axis of the drill, as shown in Fig. 16. They are used in drilling brass, and in drilling iron and steel when the holes break into one another, as shown in Fig. 17.

The smaller sizes may be made of drill rod. After cutting to length, the blank may be put in a chuck in the lathe and the end pointed to the proper cutting angle. When milling the flute, the shank may be held in the chuck on the end of the spiral head spindle. The head should be set at an angle that makes the flute deeper at the cutting end of the drill than at the shank end; this causes an increase of thickness at the shank, thus making the drill stronger than if the flute were of uniform depth throughout. The

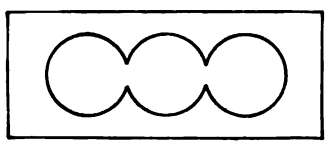


Fig. 17.

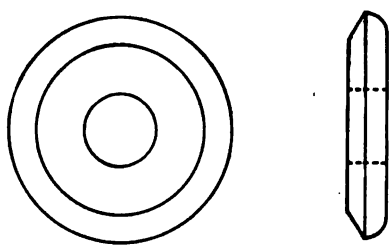


Fig. 18.

milling cutter should be of a shape that will make the cutting face of the drill a straight line when the drill is ground to the proper cutting angle. The corner should be somewhat rounded. The general shape of the cutter is shown in Fig. 18.

Single Lip Drill. For certain classes of work the single lip drill is very useful. Having but one cutting edge its action is similar to that of a boring tool used for inside turning in the engine lathe. The body of the drill being the size of the hole drilled insures its cutting a straight hole, even when used in drilling work partly cut away, or castings having blow-holes or similar imperfections. It does not cut as rapidly as the other forms, consequently is not used where a twist drill would do satisfactory work. Fig. 19 shows a form of single lip drill to be used with a bushing. The steel for this drill should be somewhat larger than finish size, in order that the decarbonized surface may be removed;

the cutting end A and the shank B should be turned .014 to .020 inch larger than finish diameter to allow for grinding after the drill is hardened. The portion C should be turned to finish size and stamped. In order that the drill may be ground to size after it is hardened it will be found necessary to face the end back,

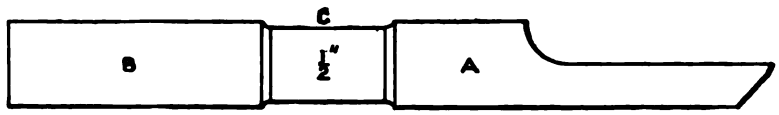


Fig. 19.

leaving the projection containing the center as shown at A in Fig. 20. The cutting end should be milled to exactly one-half the diameter of B. After milling, the face C should be draw-filed until it is flat and smooth. When hardening, the drill should be

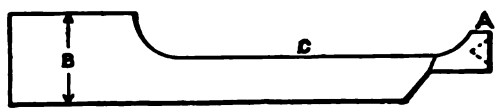


Fig. 20.

slowly heated to a low red, a trifle higher than the portion that is to be cutting size; it should be plunged in a bath of warm water or warm brine in order to avoid as far as possible any tendency to

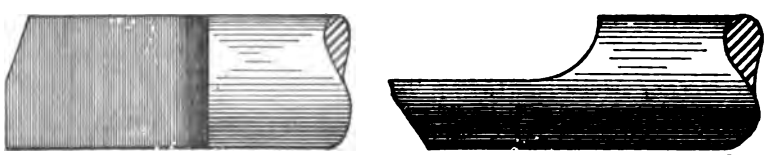


Fig. 21.

springing or cracking in the projection A. The tendency to crack is due to its peculiar shape and the difference in its size and that of the drill. After hardening it may be drawn to a straw color.

When grinding it is advisable to grind the shank first, in order that the grinding machine may be adjusted to grind straight;

after grinding the shank and cutting end to size, the projection A may be ground off, and the cutting end given the required shape, as shown in Fig. 21.

When a single-lip drill is to be used on iron and steel and not upon brass, it may be made to cut more freely by giving the cutting-face rake, as shown in Fig. 22. This may be done by mill-

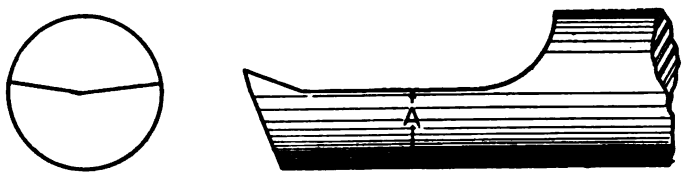


Fig. 22.

ing the portion A to the proper dimensions, which should be one-half the diameter of the blank. The end and sides of the drill may now be coated with the blue vitriol solution and the desired shape marked out, after which it may be placed in the milling machine vise at the proper angle, and the required

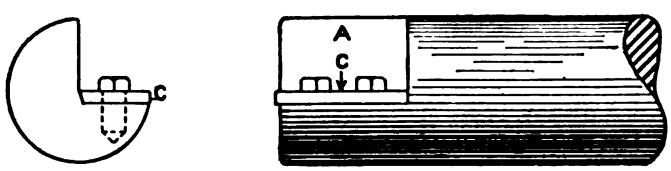


Fig. 23.

amount of rake given by means of small end cutters. After giving the necessary end clearance as shown in the two views of Fig. 22, the drill is ready for hardening.

In order to adjust a drill of this kind to compensate for wear, it may be made as shown in Fig. 23, in which one-quarter of the circumference is cut away at A and a blade or cutter fastened in position; the top face of the cutter should be radial. To compensate for wear, pieces of paper or thin sheet metal may be inserted under the blade.

When cutting away the portion A, three holes may be drilled, as shown in Fig. 24. If square corners are desired, care should be taken that the holes are located so that they will machine out when milling to the proper dimensions. After drilling, the body of the drill may be placed in a vise in the shaper, and by the use of a cutting-off tool (parting tool) the portion may be removed, but as it would be impossible to cut to finish dimensions it will be necessary to finish with small end milling cutters, holding the tool in the chuck on the spindle of the spiral head. After machining one surface, the spindle may be revolved one quarter turn and the other surface machined; this insures square corners, and two surfaces at right angles to each other. The surface on which the cutter is to rest should be cut below the line of center, so that the top edge of cutter may be radial; that is, it should be cut the thickness of the cutter below a line passing through the center. See Fig. 23.

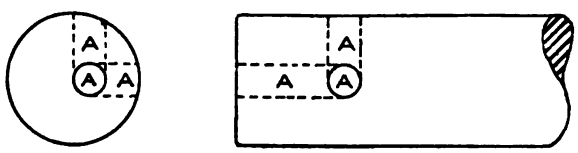


Fig. 24.

The cutter should be made of tool steel; two holes should be drilled for the fastening screws. After fastening the cutter in position it may be turned to the proper diameter by running the body of the tool in the steady rest of the lathe. Care should be used not to cut into the body or holder. After turning to size and facing the end square, the cutter may be removed from the holder, and necessary clearance given the end by filing; the outer edge may be draw-filed in order to smooth it, and a slight clearance given to prevent binding; this may be done by removing a trifle more stock at the bottom than at the top edge. To harden it should be heated to a low red heat and dipped in luke-warm water; the temper may be drawn to a straw color.

Twist Drills. In general it is cheaper and more satisfactory to buy twist drills than to attempt their manufacture in the ordi-

nary machine shop; but at times a *special* size or length of drill is needed, or, for some cause, it is necessary to make them.

For the smaller sizes it is best to use commercial drill rod. For drills larger than $\frac{1}{2}$ inch diameter select larger stock and turn it to the desired size. If true holes of the size of the drill are required, it is advisable in the case of drills larger than $\frac{1}{2}$ inch diameter, to turn them .010 to .015 inch larger than finish size, and grind to the required size after hardening. A projection (Fig. 25) containing the center should be left on the cutting end of the

Fig. 25.

drill until after the grinding has been accomplished. After cutting the flutes and grinding the drill, the projection may be ground off and the cutting lips ground to the proper shape, as shown in Fig. 26.

When making drills of the smaller sizes from drill rod, the blanks may be cut and pointed to the proper angle on the cutting end; this may be done in the lathe holding the blank in a chuck.

Fig. 26.

The proper angle is 59° from one side of the blank. When milling the flutes of a twist drill on a universal milling machine, the shank of the drill, if straight, may be held in a chuck or collet of the right size, and if very long may be allowed to pass through the spiral head.

The following explanation and table are taken from Brown & Sharpe Co.'s book, entitled "Construction and Use of Milling Machines," and are intended for use with the cutters manufactured by them when cutting the flutes in twist drills.

The cutter is placed on the arbor directly over the center of the drill, and the bed is set at the angle of spiral, as given in the following table:

Diameter of Drill.	Thickness of Cutter.	Pitch in Inches.	Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	Angle of Spiral.
1/16	.06	.67	24	86	24	100	16° 20′
1/8	.08	1.12	24	86	40	100	19° 20′
3/16	.11	1.67	24	64	32	72	19° 25′
1/4	.15	1.94	32	64	28	72	21°
5/16	.19	2.92	24	64	56	72	20°
3/8	.23	3.24	40	48	28	72	21°
7/16	.27	3.89	56	48	24	72	20° 10′
1/2	.31	4.17	40	72	48	64	20° 30′
9/16	.35	4.86	40	64	56	72	20°
5/8	.39	5.33	48	40	32	72	20° 12′
11/16	.44	6.12	56	40	28	64	19° 30′
3/4	.50	6.48	56	48	40	72	20°
13/16	.56	7.29	56	48	40	64	19° 20′
7/8	.62	7.62	64	48	32	56	19° 50′
15/16	.70	8.33	48	32	40	72	19° 30′
1	.77	8.95	86	48	28	56	19° 20′

The depth of groove in a twist drill diminishes as it approaches the shank, in order to obtain increased strength at the place where the drill is otherwise generally broken. The variation in depth depends on the desired strength or the use of the drill. To obtain the necessary variation of depth, the spindle of the spiral head is elevated somewhat, depending on the length of the flute to be cut; when less than 2 inches in length the angle should be ½ degree: 5 inches and over in length, 1 degree. Usually this will be found satisfactory, but for extremely long drills the elevation must exceed these amounts. The outer end of the drill must be supported, as shown in Fig. 27, and when small should be pressed down firmly until the cutter has passed over the end.

It is somewhat better to use left-handed cutters, so that the cut may begin at the shank end, in order to lessen the tendency of lifting the drill blank from the rest. When large drills are held by the centers the head should be depressed in order to decrease the depth of the groove as it approaches the shank.

Another very important operation on the twist drill is that of "backing off" the rear of the lip, to give it the necessary clearance. In Fig. 28 the bed is turned to about ½ degree, as for cutting a right-hand spiral, but as the angle depends on several conditions it will be necessary to determine what the effect will be under different circumstances. A study of Fig. 28 will be sufficient for this by assuming the effect of different angles, mills, and the pitches of spirals. The object of placing the bed at an

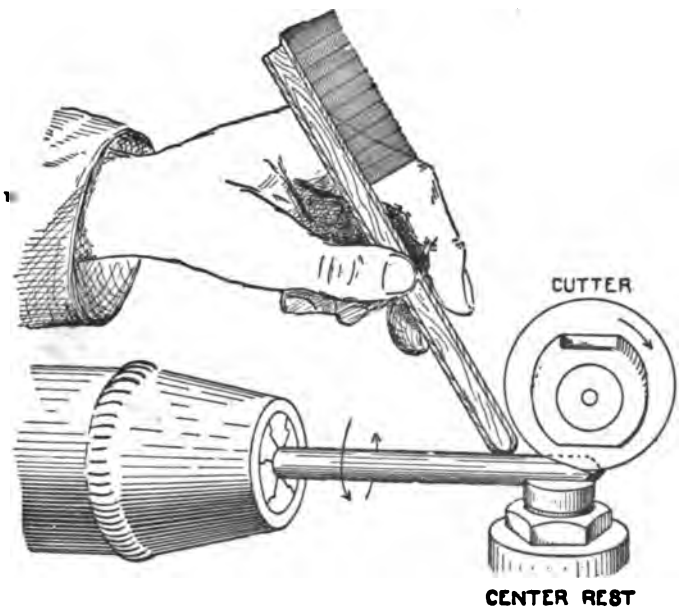


Fig. 27.

angle is to cause the mill E to cut into the lip at C and have it just touch the surface at C. The line R being parallel with the face of the mill, the angular deviation of the bed is clearly shown at A in comparison with the side of the drill.

While the drill has a positive traversing and relative movement, the edge of the mill at C must always touch the lip a given distance from the front edge, this being the vanishing point; the other surface forming the real diameter of the drill is beyond the reach of the cutter, and is left to guide and steady it while in use.

The point C as shown in the enlarged view, Fig. 28, shows where the cutting commences and its increase until it reached a maximum depth at C, where it may be increased or diminished according to the angle employed in the operation; the line of cutter action being represented by I I.

Before backing off, the surface of the smaller drills in particular should be oxidized by heating until it assumes some distinct color to clearly show the action of the mill on the lip of the drill, for, when satisfactory, a uniform streak of oxidized surface, from the front edge of the lip back, is left untouched by the mill, as represented in the cut at E.

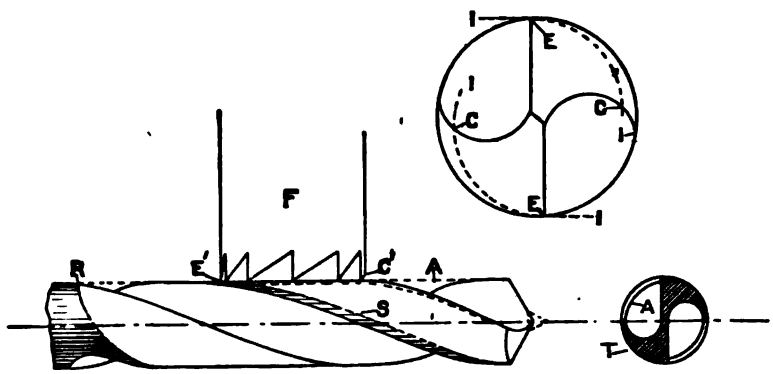


Fig. 28.

If the drills are to be ground without being centered, pointed projections (60°) may be made on the ends as shown in Fig. 28; these projections may be run in female centers in the grinding machine. If tapered back about .003 inch in 6 inches it will be found that the clearance thus obtained will cause them to run much better.

Hardening Twist Drills. Twist drills are hardened by special processes which, generally speaking, are not understood outside the shop where the drills are made. Very good results, however, may be obtained if the drills are heated somewhat and dipped into a solution of the following:

Pulverized charred leather	1 pound
Fine Family Flour	1½ pounds
Fine Table Salt	2 pounds

The charred leather should be ground or pounded until fine enough to pass through a number 45 sieve. The three ingredients are thoroughly mixed while in the drv state, and water is then added *slowly*, to prevent lumps, until the mixture formed has the consistency of ordinary varnish.

After the drill has been dipped in the mixture it should be laid in a warm place to dry; when thoroughly dried the drill may

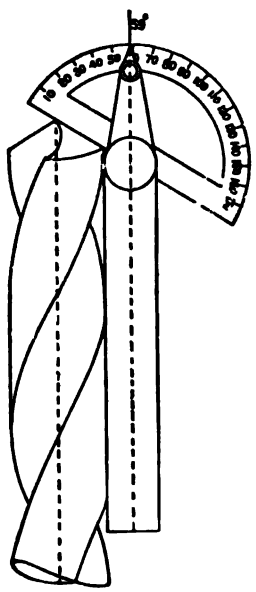


Fig. 29.

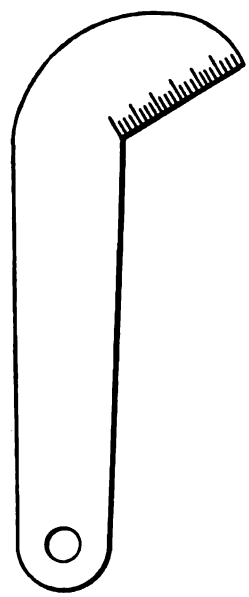


Fig. 30.

be heated in a tube, or preferably in a crucible of red-hot lead until it is a low red, when it may be plunged in a bath of luke-warm water, or brine; small drills may be dipped in a bath of oil. The drill must not be put in red-hot lead until the coating is thoroughly dried, as the moisture may cause minute particles of lead to fly in all directions, endangering the eyes of the operator. After hardening, the temper may be drawn to a full straw color. If several drills are hardened at a time the temper may be drawn by placing them in a kettle of oil over a fire gauging the amount of heat by a thermometer, as explained under heading of "Drawing Temper."

Grinding Twist Drills. The cutting edges must make a proper and uniform angle with the longitudinal axis of the drill; they must be equal in length, and the lips of the drill sufficiently backed off for clearance, otherwise they will not cut easily, or they will make a hole *larger* than the size of the drill.

Drills properly made have their cutting edges straight when ground to a *proper* angle, which is 59 degrees, as in Fig. 29. Grinding to an angle less than 59 degrees leaves the lip hooking, which is likely to produce a crooked and irregular hole.

A very satisfactory form of angle gauge for this work is shown in Fig. 30; the graduations on the upper part of gauge show when the lips are ground to an equal length, which is essential in order that the drill shall cut the proper size. As the operator becomes experienced he can gauge the angle and length of lips very accurately by the eye, but until he has the necessary experience it is advisable to use some form of gauge.

REAMERS.

A reamer is a tool that makes a smooth, accurate hole; however, in many cases reamers are used to enlarge a cored hole, or a hole already drilled, without particular reference to the exact size or condition of the hole. Reamers may be classified according to

Fig. 31.

shape as follows: straight reamers, taper reamers, and formed reamers. Reamers are made solid, adjustable, and with inserted blades.

Solid reamers (Fig. 31) are so called because the cutting teeth and head are made from one piece; they have no means of adjustment as to size. The cutting teeth of inserted blade reamers are made from separate pieces of steel, and inserted in the head as shown in Fig. 32. The adjustable reamer may be made with inserted teeth, or with cutting teeth solid with the head; but in either case having some means of adjusting the size.

STRAIGHT REAMERS.

Under this heading the following kinds of reamers are to be found: fluted hand reamers, fluted chucking reamers, rose reamers, single lip reamers, and three and four lipped roughing reamers.

The Fluted Hand Reamer is made straight on the cutting lips, with the exception of a short distance at the end (A Fig. 33) which is slightly tapered in order that the reamer may enter the hole. In making such reamers, use steel from $\frac{3}{32}$ inch to $\frac{1}{8}$ inch above finish size. Turn a chip off the outside surface to a depth

Fig. 32.

of $\frac{1}{32}$ inch and anneal, then turn A and B Fig. 33 to sizes .010 to .015 inch larger than finish size; turn C to finish size, mill the end D square for a wrench. The reamer is now ready to have the flutes cut.

Number of Cuttting Edges. Fluted reamers designed to remove but a small amount of stock, and intended to cut holes to an accurate size are rarely given less than six flutes.

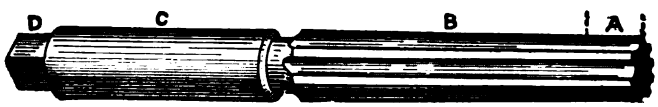


Fig. 33.

The following table gives the number of cutting edges that give satisfaction for solid reamers whose flutes are milled by cutters made to give the proper shape.

TABLE OF CUTTING EDGES FOR REAMERS.

$\frac{1}{8}''$ to $\frac{7}{16}''$ diameter	6 teeth
$\frac{1}{2}''$ to $\frac{11}{16}''$ "	6 to 8 "
$\frac{3}{4}''$ to $1''$ "	8 "
$1\frac{1}{16}''$ to $1\frac{1}{4}''$ "	10 "
$1\frac{5}{16}''$ to $2\frac{1}{2}''$ "	12 "
$2\frac{1}{2}''$ to $3''$ "	14 "

Formerly it was considered necessary to have an odd number of cutting edges; but an even number if unevenly spaced will be as satisfactory. The chief objections to an odd number are the difficulty experienced in calipering unless a ring gauge is used, and the great cost of grinding.

Fig. 34 shows a form of cutter that makes a strong reamer tooth and allows the chips to be removed very readily. These cut the tooth ahead of the center, and should be given a negative rake of about 5°. In general, a reamer will cut more smoothly if the tooth has a slight negative rake, as it then takes a scraping cut.

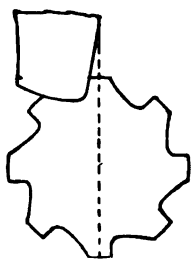


Fig. 34.

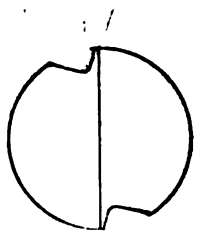


Fig. 35.

With this form of flute, the depth of cut must be so gauged that the land will be about $\frac{1}{6}$ the average distance from one cutting edge to the other; if cut deeper, the teeth will be weak and have a tendency to spring, if not as deep, there will not be room for the removal of the chips. The following table shows the number of cutter (shown in Fig. 34) for any size of reamer.

NUMBERS OF CUTTERS FOR REAMERS.

No. 1	Cutter	cuts	reamers	from	$\frac{1}{8}''$ to $\frac{5}{16}''$	diameter.
No. 2	"	"	"	"	$\frac{1}{4}''$ to $\frac{9}{16}''$	"
No. 3	"	"	"	"	$\frac{3}{8}''$ to $\frac{7}{16}''$	"
No. 4	"	"	"	"	$\frac{1}{2}''$ to $1\frac{1}{16}''$	"
No. 5	"	"	"	"	$\frac{3}{4}''$ to $1''$	"
No. 6	"	"	"	"	$1\frac{1}{16}''$ to $1\frac{1}{8}''$	"
No. 7	"	"	"	"	$1\frac{9}{16}''$ to $2\frac{1}{8}''$	"
No. 8	"	"	"	"	$2\frac{1}{4}''$ to $3''$	"

In order that reamers may be calipered readily when grinding — if the teeth have been unevenly spaced — the teeth must be diametrically opposite each other; the unevenness in spacing must

be between adjoining teeth. This is done by cutting one tooth, then turning the spiral head of the milling machine half-way round (by giving the index pin twenty revolutions) and then cutting the opposite tooth. When cutting the flutes in pairs, the number of times the cutter must be set for depth of cut is reduced one half. Fig. 35 shows an end view of reamer having the first pair of flutes cut as described.

The irregularity of spacing is obtained by moving the index pin a different number of holes for each adjoining pair of flutes.

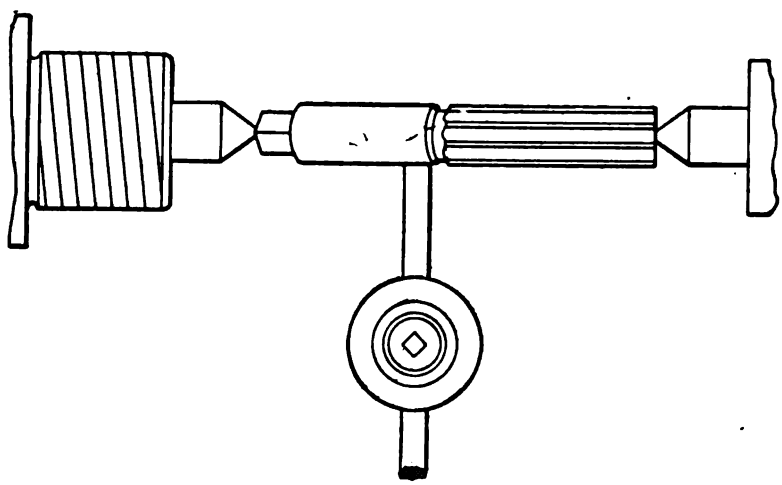


Fig. 36.

This irregularity need not be great; a variation of a few degrees, 2°, 3° or 4° from an angle corresponding to regular spacing is generally considered good practice.

Hardening Reamers. In order that a reamer may not spring when hardened, great care should be exercised in heating. If a muffler furnace is at hand, a uniform heat may be obtained. If heated in a blacksmith's forge the reamer should be placed in a tube to prevent the fire from coming in contact with the steel; it should be turned frequently to insure uniform results. While cooling, the reamer should be held vertically to avoid springing, and should be worked up and down in the bath.

If the reamer is one inch diameter, or larger, it should be

removed from the hardening bath when it stops *singing*, and plunged into oil, and allowed to remain until cold. The temper may be drawn to a light straw color.

If reamers are hardened by the "Pack Hardening" process, the danger of springing is greatly reduced.

Straightening Reamers. If a reamer springs while hardening and tempering, it may be straightened by the following method: Place the reamer between the centers of the lathe; fasten a tool, or piece of iron or steel having a square end in the tool

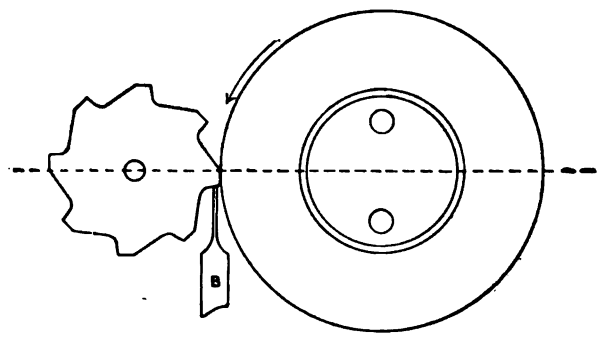


Fig. 37.

post (Fig. 36), placing the square end against the reamer at the point of greatest curvature. The surface of the reamer should be covered with a thin coating of sperm, or lard oil. With a spirit lamp, a plumber's hand torch, or a Bunsen burner, heat the reamer evenly until the oil commences to smoke; pressure may now be applied by means of the cross-feed screw, slowly forcing the reamer over until it is bent a trifle the other way. It should be cooled evenly while in this position. After it is cool the pressure may be relieved and the reamer tested for truth. If it does not run true the operation may be repeated. This method of straightening is equally effective when applied to other classes of work.

The straightening should be done before drawing the temper. When drawing the temper the heat should be applied evenly or the piece will spring from uneven heating.

Before *grinding a reamer* be sure that the centers of the grinding machine are in good shape, then clean the centers of

the reamer. The reamer should first be ground to run true. It may be ground to within .001 or .002 inch of finish size; large reamers having the greater amount. In backing off a reamer tooth for clearance use an emery wheel of as large diameter as possible without striking the cutting edge of the next tooth. The correct clearance is given by a finger which can be adjusted. Fig. 37 shows an end view of reamer being ground for clearance together with the finger and emery wheel. The emery wheel should run in the direction indicated by the arrow, in order that the pressure of the wheel will tend to force the reamer tooth down on the finger B. To give clearance, the finger is adjusted so that the cutting edge is below the line of centers as shown. The lower the finger the greater the amount of clearance. Unless a free cutting wheel, free from glaze is used the temper will be drawn, thus rendering the reamer worthless. To avoid softening the teeth, the stock must be removed by a succession of light cuts going way around the reamer each time the adjustment is changed.

A reamer will soon lose its size if the clearance is ground to the edge of the teeth; consequently it is best to grind to within from .01 to .015 inch of the edge, according to the size of the reamer. The reamer is then brought to an edge and to the desired size by oilstoning. To do satisfactory work the stone should be free cutting. Select a stone of medium grade for removing the stock, and use a "fine" stone for finishing the cutting edge. An oilstone should *not* be used dry; keep the face free from glaze. If there are deep depressions or marks in the stone, face it off on a wet grinding machine.

Fluted Chucking Reamers. The same general instructions given for making fluted-hand reamers, can be applied to this form; except that the shank may be finished to size before the reamer is hardened, unless the shank is to fit a collet or be held in a chuck.

The regular jobbing reamer used in the lathe is shown in Fig. 38; the form for the chucking lathe or drill press, where the shank is held in a collet or chuck is shown Fig. 39. When making this style of reamer, B may be left .010 to .015 inch above size to allow for grinding. The portion C may be finished to size and the dimension of the cutting part of the reamer stamped on it as shown; if the reamer is made for special work and is to be used

on no other, the name of the piece, or operation it is intended for should also be stamped.

On account of the uncertainty of a reamer cutting exactly to size when used in a lathe, chucking reamers are frequently made somewhat under size. Standard *hand* reamers are used for finishing. The amount of stock left for the hand reamer varies: some tool makers consider .005 inch the proper amount for all reamers up to 3 inches in diameter; while others think that for 1 inch or less diameter .004 inch is right; and for sizes from $1\frac{1}{16}$ inches to 2 inches, .007 inch should be allowed. For reamers larger than

Fig. 39.

2-inch diameter an allowance of .010 inch should be made. The exact amount necessary for finishing with hand reamers depends on the nature of the work and the stock operated on. Fluted chucking reamers are made with either straight or spiral flutes.

When a reamer is used in a screw machine or turret lathe, on work where accuracy and straightness of hole is essential, it should be held in some form of special holder, which allows it to properly

Fig. 39.

locate itself as to alignment. Such holders will be described later under the heading "Reamer Holders."

Rose Reamers. This form of reamer has its cutting edges only on the end as shown in Fig. 40, the grooves being cut the entire length of body to reduce the amount of frictional-bearing surface and to furnish a channel to conduct the lubricant to the cutting lips. In case there are blow holes or other imperfections

in the material being operated on, this reamer will cut a more nearly parallel hole than the fluted chucking reamer.

Fig. 40 shows the ordinary form of rose chucking reamer. The shank B is turned to finish size; in case it is to fit a holder it is left slightly larger and turned or ground to size after hardening. The body A is turned .015 to .020 inch above finish size, the flutes cut, the size stamped as shown, and the reamer hardened

Fig. 40.

a little above the body. It is customary when grinding a rose reamer to make it a trifle smaller on the end of body next to the shank; a taper of $\frac{1}{4000}$ inch in the length of the cutting part gives good results.

Small rose reamers can be made of drill rod, which runs very true to size, if ordered by the decimal equivalent rather than by the drill gauge number, or in terms of common fractions. For

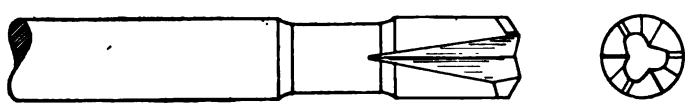


Fig 41.

instance, if drill rod is wanted of a size corresponding to No. 1 Browne & Sharpe drill gauge, the wire will come much more accurate if ordered .228 inch diameter rather than by the gauge.

The wire may be sawed to length, put in lathe chuck, and cornered for the cutting lips. When making small reamers that are not to be ground to size after hardening, it is advisable to neck them down back of the cutting edge, as shown in Fig. 41. The drill rod often swells or expands at a point where the harden-

ing ends, and by necking down and hardening into the necking this difficulty is overcome.

Small rose reamers may be given three cutting edges. The flutes may be filed with a three-square or a round-edge file. If a three-square file is used, a groove of the form shown in Fig. 41 may be made. This has a tendency to push the chips ahead when cutting, while a groove filed with a round-edge file, if it be of a spiral form, will draw the chips back into the flute, provided it is a right-hand helix, as shown in Fig. 42.

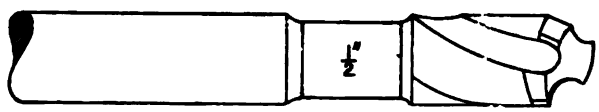


Fig. 43.

Rose reamers intended for reaming holes of exact size must be ground to correct dimensions after hardening, but small reamers intended for reaming holes where *exactness* of size is not essential may be made to size before hardening, and the cutting edges backed off with a file for clearance. If reamers are ground on the circumference for size, the lips or cutting edges should be

Fig. 43.

given clearance by grinding. After grinding, the corners of the cutting edges next to the body of the reamer, as shown at C, Fig. 40, should be rounded by oilstoning.

A Single Lip Reamer is very useful for reaming a *straight* hole. When the nature of the hole or the condition of the stock would cause the ordinary forms to *run*, the single lip reamer will cut a straight hole if started right. Having but one cutting lip, its action is similar to a boring tool used for internal turning in

the lathe, and as a large proportion of the body of the reamer acts as a guide, it must cut a straight hole. Fig. 43 shows two views of this form of reamer.

Steel for this reamer should be sufficiently large to allow the decarbonized surface to be entirely removed. After a roughing chip has been taken,— leaving the piece about $\frac{1}{16}$ inch above finish size,— the stock should be annealed, after which the portions A and B should be turned to a size that allows for grinding. C may be finished to dimensions given, and the size of the reamer stamped as shown.

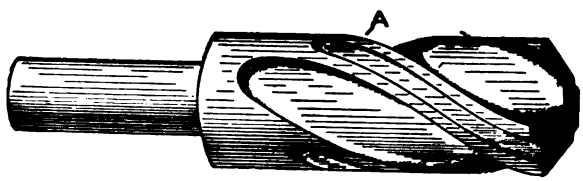


Fig. 44.

The reamer is now ready for milling. This should be done with the reamer in the centers in the milling machine, using a shank mill or a small milling cutter on an arbor. The depth of the cut should be about one-third the diameter of the reamer; for large reamers it may be somewhat deeper. After milling, the face may be smoothed with a fine file, and the end and cutting lip backed off for clearance, as shown in Fig. 43 at D and E.

When hardening, the end A should be heated to a low red and dipped in the bath about one-half an inch on the necked portion C. The temper may be drawn to a light straw. A and B are now ready for grinding. If the grinder has no provision for water to run on the work, care should be used not to heat the reamer, as it is likely to spring.

Three and Four Lipped Roughing Reamers are used to advantage in chucking machines for enlarging cored holes, or holes that have been drilled smaller than the required size. This is often done in making large holes in solid stock, as most manufacturers consider it more economical to use a smaller drill and a

roughing reamer in order to bring them to proper size for the final reamer. Fig. 44 shows a reamer of this description.

The instructions already given for making the various reamers may be followed for this form, with the exception of cutting the grooves, which should be of a sufficient size to hold the chips. The small groove cut in the center of the lands is to feed oil to the cutting edges when cutting steel. When cast iron is the material to be operated on, the grooves are cut straight and the oil groove omitted. If a finish reamer is to be used in sizing the

Fig. 45.

holes, it is customary to make the roughing reamer $\frac{1}{64}$ inch smaller than finish size. On account of the rough usage, great care should be exercised in hardening. While satisfactory results may be obtained by heating to a *low* red, plunging in a bath of brine, and drawing the temper to a light straw, the tools will do a great deal more if they are pack hardened by the process already described.

Inserted Blade Reamers. The particular advantage of solid reamers with inserted teeth is that when worn, new blades may be put in at a cost much less than that of a new solid reamer. Inserted blade reamers are usually made in such a manner that the size may be altered; in such cases they are termed expanding reamers. A simple form is shown in Fig. 45. The slots for the blades are milled somewhat deeper at the front end than at the end toward the shank; they are also somewhat wider at the bottom than at the top. The first is accomplished by depressing the spiral head a trifle, while the latter is done by first milling the slots with a cutter a little narrower than the top of the slot wanted, then turning the spiral head enough to produce the desired angle on one side of slot as shown at A in Fig. 46. The object in making

Fig. 46.

the slot deeper at the front end is that the blades, as they become dulled (and consequently cut small), may be driven farther into the body. As the slot is shallower, the blade is forced out as it advances, thus increasing its diameter; it may then be sharpened by grinding to size. The side of the slot is cut at an angle to hold the blade solidly and prevent any tendency it might have to draw away from its seating when the reamer is cutting. The body of the reamer is not hardened; the blades are machined to size, hardened, driven into place and ground to size. If the

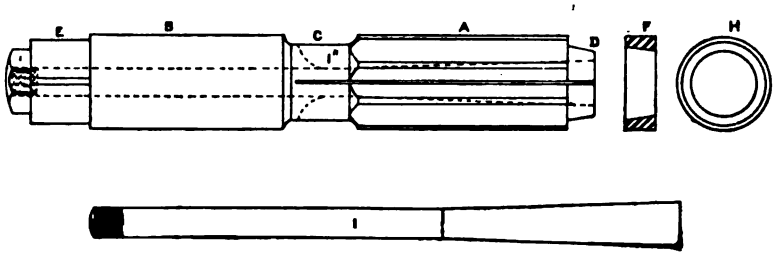


Fig. 47.

reamer is of the form known as *fluted reamer*, the teeth may be backed off for clearance as already described.

Adjustable Reamers are made of a form that allows them to be adjusted to a varying size of parts of machines where interchangeability is not essential. Fig. 47 shows the cheapest form of adjustable reamer; this form is sometimes objected to because it does not expand or contract uniformly its entire length; for ordinary work, however, it is very satisfactory, if used for a limited range of sizes.

Stock should be selected at least $\frac{2}{32}$ inch larger than finish size. After carefully centering and squaring the ends, a chip should be turned the entire length of the piece. It should then be drilled, and the taper hole reamed for the expansion plug. When drilling the outer end, the blank should run in the steady rest; the hole in the *shank* end should be drilled to the proper depth with a drill $\frac{1}{32}$ inch *larger* than the straight stem of the expansion plug. The end should be chamfered to a 60° angle to

run on the lathe center when turning and grinding. The piece may be reversed and the opposite end drilled and reamed with a taper reamer; this end should be chamfered also to a 60° angle. Fig. 48 shows a sectional view of the blank drilled and reamed, and the ends of the hole beveled.

The reamer may now be turned .020 to .025 inch above finish sizes on A and B, while C and D may be turned to finish sizes, and the size stamped at C. The end E may be milled square for a wrench, the grooves milled and the reamer split, in order that the size may be altered with the expansion plug.

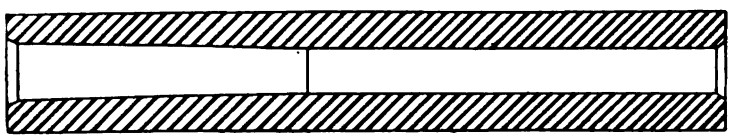


Fig. 48.

When splitting the reamer, a metal slitting saw of the required thickness (usually $\frac{1}{16}$ inch) should be used. The saw cut should not extend to the end of the reamer, but a small portion should be left solid to prevent the reamer from springing when hardening. The circular saw leaves a cut at the end of the shape shown in Fig. 49, which would be extremely difficult to part after hardening. In order that the thin partition of stock may be easily severed with an emery wheel, the slot may be finished, as shown in Fig. 50, with a hand hack saw.

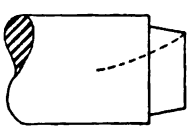


Fig. 49.

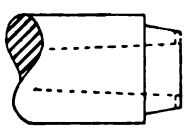


Fig. 50.

The expansion rod I, Fig. 47, should be turned to fit the taper in the reamer, the straight end should be $\frac{1}{32}$ inch smaller than the hole running through the reamer, and should be threaded on the end for a nut to be used in drawing the rod into the reamer. The collar shown at F and H should have a taper hole fitted to the tapered end of the reamer. The outside diameter of collar should be a trifle smaller than the hole to be reamed; this

collar, when forced onto the end of the reamer, holds it in place. In order to increase the size of the reamer, the collar may be driven back a trifle and the rod drawn in by means of the nut.

After the reamer is hardened and tempered, the thin partitions left at the ends of the slots may be ground away with a beveled emery wheel, the rod inserted, the collar forced on the end, the reamer ground to size, and the teeth backed off for clearance.

TAPER REAMERS.

If a taper reamer is intended for finishing a hole, the same general instructions may be followed as for *fluted hand reamers*, except that instead of being straight, the body, or cutting part, is tapered.

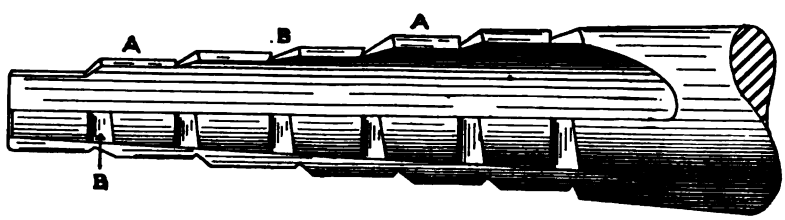


Fig. 51.

Roughing taper reamers are frequently made in the form of a stepped reamer, or it might be called a multiple counterbore, since each step acts as a pilot for the next larger step, as shown in Fig. 51. The steps A are turned straight, each one correspondingly larger than the preceding. The cutting is done at the end of the step B, which must be given clearance; this is ordinarily done with a file. The reamer may be given four cutting edges; these should be cut with a milling cutter intended for milling the flutes of reamers. The number of the cutter selected will depend on the form and amount of taper of the reamers. It is advisable to neck down into the reamer $\frac{1}{32}$ inch at the end of each step; this may be done with a round nose tool, or a cutting-off tool having its corners slightly rounded. The necking facilitates the filing of the cutting edges, and also allows the emery

wheel to traverse the entire length of each step when grinding to size after hardening.

Roughing reamers are sometimes made of the form shown in Fig. 52. The left-hand thread cut the entire length of the cutting portion breaks the chips into short lengths, and greatly increases the cutting qualities. After turning the tapered part to a size that allows for grinding, the lathe may be geared to cut a four-pitch thread. The threading tool should be about $\frac{1}{16}$ inch thick at the cutting point, and have sufficient clearance to prevent the heel dragging when the tool is cutting. The corners should be slightly rounded in order to reduce the tendency of cracking when the reamer is hardened. The thread should be cut to a

Fig. 52.

depth of from $\frac{1}{64}$ to $\frac{1}{32}$ inch. After threading, the flutes may be cut, the reamer hardened, and the temper drawn to a light straw.

When grinding a *taper reamer* the proper clearance is given to the tooth back for a distance of $\frac{3}{64}$ inch from the cutting edge, the balance of the tooth is given a greater amount of clearance, as shown in Fig. 53.

Shell Reamers. As a matter of economy, the larger sizes of reamers are sometimes made in the form of shell reamers, as shown in Figs. 54 and 55. As several reamers may be used on the same arbor, there is quite a saving in cost of material.

The following table gives the size and length of shell reamers from one inch to three inch diameter, together with the size of holes, and width and depth of tongue slot.

			Tongue Slot.	
Diameter.	Length.	Size of Hole.	Width.	Depth.
1″ to 1¼″	2¾″	⅜″	¼″	¼″
1 5/16″ to 1⅜″	3″	⅜″	5/16″	5/16″
1 7/16″ to 2″	3¼″	1″	⅜″	5/16″
2 1/16″ to 2½″	3¾″	1¼″	½″	⅜″

After drilling a hole $\frac{1}{16}$ inch smaller than finish size, the blank should be placed on a mandrel and a heavy chip taken to remove all the original surface. It should then be annealed.

After annealing it may be placed in a chuck on the lathe and the hole bored .005 inch smaller than finish size. After putting on a mandrel, the ends should be faced to length and the outside diameter turned, leaving .010 to .015 inch on the cutting part for grinding. The balance of reamer should be turned to size. If it is to be a *rose reamer* the edge should be chamferred the proper amount.

The reamer should be held in a chuck on the spiral head spindle in the milling machine, and the tongue slot cut. In order

Fig. 53.

Fig. 54.

Fig. 55.

to get the slot central with the outside of the reamer, a cutter somewhat narrower than the desired slot should be used, which should be set as centrally as possible by measurement, a cut taken, the spiral head turned one-half way round and another cut taken; the width of the slot should be measured, and the saddle of the machine moved by means of the graduated adjusting screw one-half the amount necessary to make the slot of the right width. The reamer may now be placed on a mandrel between centers on the milling machine, and the grooves cut.

The reamer should be heated for hardening in some receptacle in order that the fire may not come in direct contact with it; when it reaches a *low uniform* red heat it may be placed on a wire bent in the form of a hook, and plunged in the bath; it should be worked up and down rapidly until all trace of red has disappeared. When cold it may be heated to prevent cracking from internal strains; if it is to be a rose reamer it may be left *dead* hard, if a fluted reamer the temper should be drawn to a straw color. The hole should be ground to fit the shank on which it is to be used,

or a plug gauge, if there is one for the purpose. The reamer may then be placed on a mandrel and ground according to directions given for grinding reamers.

The holes in *shell reamers* are sometimes made tapering — the end of the arbor being made of a corresponding taper — to avoid the necessity of grinding the holes, as any slight change in the size resulting from hardening would be compensated for by the taper hole.

Arbors for Shell Reamers are made as shown in Fig. 56. The shank B and end A to receive the reamer, are made in one piece. The collar C having two tongues to engage in the slots in the reamer, is made of tool steel; the hole is made of a size that allows it to slide over A. When in position a hole is drilled through both collar and arbor and the pin D driven in. When making the collar the hole is drilled and reamed; it is placed on a mandrel, the ends faced to length, and the collar turned to proper

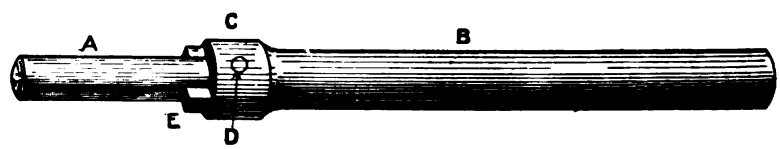


Fig. 56.

diameter. It is then removed from the mandrel and the tongues milled. While doing this the collar is held in the chuck on the spindle of the spiral head and a side milling cutter is used. One side is milled, the spiral head spindle turned one-half revolution, and the opposite side milled; the thickness is measured and the saddle moved enough to bring the tongues to the required thickness when the finish cut is taken on each side. After putting on an arbor and drilling the pin hole, the collar may be removed and spring tempered. It may now be placed on the arbor and the pin driven in place.

When the hollow mill is made with a taper hole, the arbor is made with the end A of a corresponding taper. Otherwise the construction would be the same as for hollow mills having straight holes.

Formed Reamers are used for holes of an irregular shape, or rather of a shape neither straight nor tapering. They are used

chiefly by gun makers in reaming the end of the gun barrel for the shell, and are termed, when used for this class of work, *chambering reamers.*

It is essential when making this class of reamer, that the stock be rough turned a little above finish size and then annealed. Reamers of this form are accurate as to size and shape, consequently it is customary to use a gauge. This is generally a piece of steel having a hole of the proper form reamed in it, after which the stock is cut away on one side, leaving a trifle more than one-half of the hole as shown in Fig. 57.

To make the reamer blank fit the gauge the operator must understand the use of hand turning tools, as most shapes must be made with these tools. The teeth must be cut with a milling cutter of small diameter following the different shapes of the

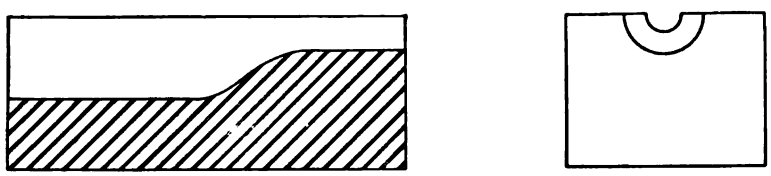


Fig. 57.

reamer in order to have the top of the land of as uniform a width as possible. After cutting, the teeth may be backed off for clearance with a file, taking care not to remove any stock at the cutting edge.

When hardening, heat very carefully in a tube until the reamer is of a *low* uniform red heat; it should then be plunged in a bath of lukewarm brine. It may be brightened and the temper drawn to a light straw. After hardening it should be tried in the gauge, and any high spots removed by oilstoning.

If a large number of reamers of one form are to be made, the grinding machine may be rigged with a form which makes it possible to grind many of the shapes in common use, but some shapes will be found quite impracticable to grind, consequently the above method of fitting before hardening must be adopted. Excellent results are obtained by hardening by the "Pack Hardening" process.

Reamer Holders. On account of the uncertainty of exact alignment of every part of a screw machine or turret lathe, it is desirable to use a holder for the reamer that allows it to properly align itself. The form of holder shown in Fig. 58 is in common use and gives excellent results. It consists of the body A which has a hole drilled and reamed its entire length; the hole must be somewhat larger than the shank of the reamer, $\frac{1}{16}$ inch being considered sufficient. The center B of tool steel should be (after hardening) .010 to .015 inch larger than the hole in the holder; the point should be ground to a 60° angle, and the straight part ground to a forcing fit in the holder. After being forced to position a hole may be drilled through the holder and center, and the

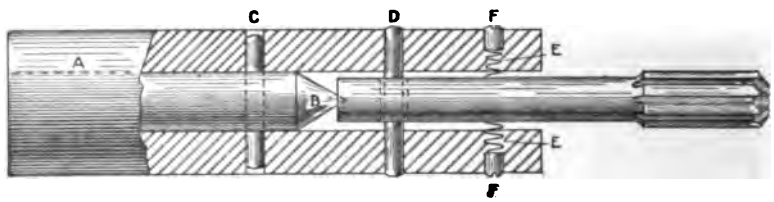


Fig. 58.

pin C driven in to keep the center from being pressed back by the reamer when in operation. A pin should be put through the holder at D; a hole $\frac{1}{16}$ inch larger than the pin should be put through the reamer shank at this point. This pin is simply to prevent the reamer from turning when it comes in contact with the work. The coil springs E E hold the reamer in position to enter the hole, and the proper tension is given by means of the screws F F.

ARBORS.

Mandrels. The ordinary taper arbor, known as the mandrel, is in common use in most machine shops. Up to and including $1\frac{1}{2}$ inches diameter, mandrels are made of tool steel, hardened all over and ground to size. Some tool makers advocate making all mandrels up to 4 inches diameter in this way; others prefer hardening the ends B B (Fig. 59), leaving the center A soft, while others maintain that for mandrels above $1\frac{1}{2}$ inches diameter, machinery steel is most satisfactory if thoroughly case hardened.

When making mandrels of tool steel that are to be hardened the entire length, it is not necessary to use the best quality of steel, as a lower grade may be used if it will harden well. Select stock somewhat larger than finish diameter, say $\frac{1}{16}$ inch for sizes up to $\frac{1}{2}$ inch; $\frac{1}{8}$ inch for sizes up to 1 inch; $\frac{3}{16}$ inch for sizes up to $1\frac{1}{2}$ inches, and $\frac{1}{4}$ inch for sizes above. Take a chip off the out-

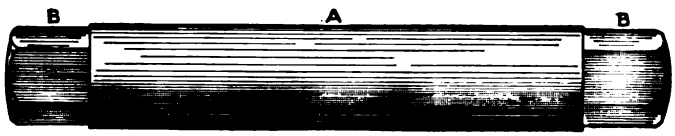


Fig. 59.

side sufficiently heavy to remove all scale, yet leaving $\frac{1}{32}$ inch for a finish cut on sizes up to $\frac{1}{2}$ inch and correspondingly more for the larger sizes. It should now be annealed, preferably in the annealing box. The ends should be countersunk deeper in mandrels than in tools where the centers are not used after they are completed, in order that the centers may not be mutilated when driven

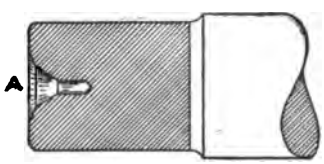


Fig. 60.

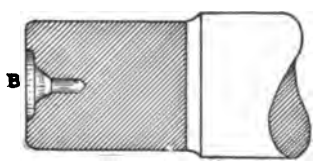


Fig. 61.

in or out of the work. The centers should either have an extra countersink, as at A in Fig. 60, or else the cut should be recessed as at B in Fig. 61.

The ends B B, Fig. 59, should be turned to size, the corners slightly rounded, and the flat spots for the dog screw milled or planed. The body of the mandrel should be turned somewhat larger than finish size; those smaller than $\frac{1}{2}$ inch should have an allowance of .015 inch; from $\frac{1}{2}$ to 1 inch an allowance of .020 to .025 inch; over 1 inch an allowance of .025 to .030. As the

length of mandrels larger than 2 inches diameter does not increase in proportion with the diameter, the amount given will generally be sufficient if proper care is used when hardening. The size should be stamped on the end next to the large end of body.

Before hardening, the centers should be re-countersunk to true them; for this operation it is best to use a special countersink having an angle of 59° instead of the regular 60° tool, as it facilitates the lapping of the centers to a 60° angle after hardening, due to the unequal amount of grinding caused by the shape of the countersinking.

If a blacksmith's forge must be used when heating the mandrel for hardening, the fire should be large enough to heat the piece evenly; it is advisable to heat it in a tube. More uniform results can be obtained from a muffler furnace than in the open fire. In either case the piece should be turned frequently, to

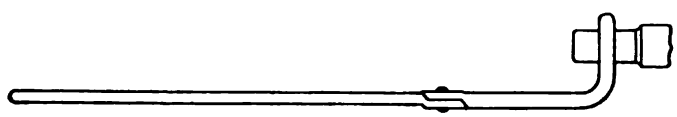


Fig. 62.

insure an even heat. To dip in the bath, a pair of tongs of the shape shown in Fig. 62 should be used, so that the bath may come in contact with both centers. The tongs should grapple the mandrel at the large end, in order that the small end may be harder; it should be worked up and down rapidly in the bath to insure uniform results. A bath of brine will be found very satisfactory for this work.

A mandrel larger than 1 inch diameter should be removed from the bath as soon as it ceases *singing*, and held in a tank of oil until cold. The ends should be brightened and drawn to a deep straw color, in order to toughen them so that they will not break or chip off when driven. Mandrels smaller than $\frac{3}{4}$ inch should have the temper drawn to a light straw color the entire length of body.

After hardening, the body of the mandrel should be cleaned with a coarse emery cloth, to remove the scale or grease which

would glaze the emery wheel. It should then be tested between centers to see if it has sprung more than will grind out before it reaches the proper size.

The centers should now be lapped, to insure proper shape and alignment. The lap may be a piece of copper of the proper shape (60°) charged with diamond dust or emery. After lapping, the centers should be thoroughly cleaned with benzine. (When using benzine do not allow it to get near a flame of any kind.)

Examine very carefully the condition of the centers of the grinder, as the truth of the mandrel depends in a great measure on their condition. A mandrel may be ground in a lathe having a grinding attachment or in any universal grinder. Better results can be obtained, however, if ground in some form of grinder having a stream of water to keep the work from heating, as heat is likely to spring the piece, especially if it does not run true, thus making the grinding heavier on one side than the other. If a dry grinder must be used, do not force the grinding fast enough to heat the piece. The mandrel should be ground to within about .005 inch of size with a coarse wheel free from glaze, and then finished with a fine wheel.

The amount of taper varies: some manufacturers prefer .0005 inch taper per inch, while others make them of .001 inch taper for every inch of length, claiming that if a piece having a long hole is to be held on *any* taper mandrel it will not fit at the end nearest the small end of mandrel, consequently the turned surface will not be true with the hole; also that for such work a mandrel should be made for the job having a body nearly or quite straight. They claim that the mandrel should be made to taper .001 inch for every inch of length, in order that it may be adapted to a greater range of work.

Mandrels with Hardened Ends. When making a mandrel whose ends are to be hard and body soft, follow the instructions given for hardened mandrels, except that a larger amount of stock should be left on the body. The ends should be hardened for a distance that insures the *centers* being hard; this can be accomplished by heating one end at a time to a red heat, and inverting under a faucet of running water. As the center is uppermost, the water can readily enter it, forcing the steam away. After

drawing the temper of the ends and lapping the centers, the body may be turned to size. The centers of the lathe should be carefully trued before starting this operation. If the body of the mandrel is left .008 inch to .010 inch larger after turning, and then ground to size, the results will be surer; but with *extreme care* a very satisfactory job may be done by the method described.

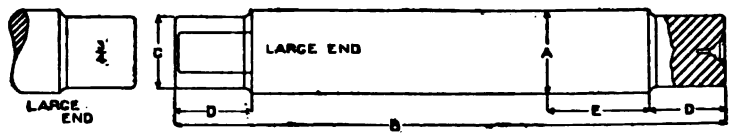


Table of Dimensions of Mandrels to 1 Inch.

A	B	C	D	E	F
1/4	3 3/4	7/32	1/2	1/2	1/8
5/16	4	9/32	1/2	9/16	5/32
3/8	4 1/4	11/32	1/2	5/8	3/16
7/16	4 1/2	13/32	9/16	11/16	7/32
1/2	5	7/16	5/8	3/4	1/4
9/16	5 1/4	1/2	11/16	13/16	9/32
5/8	5 1/2	9/16	3/4	7/8	5/16
11/16	5 3/4	5/8	13/16	15/16	11/32
3/4	6	11/16	7/8	1	3/8
13/16	6 1/4	3/4	7/8	1 1/16	13/32
7/8	6 1/2	13/16	15/16	1 1/8	7/16
15/16	6 3/4	7/8	15/16	1 3/16	15/32
1	7	15/16	1	1 1/4	1/2

Machinery Steel Mandrels. With the exception of hardening, the instructions given for making mandrels of tool steel apply to those made of machinery steel. It is necessary to *case harden* mandrels made of machinery steel, using the method already described. The work should be run in the fire from seven to ten hours after the box is red hot throughout; dip in a

a bath having a jet of water coming up from the bottom to force the steam away from the work, to avoid soft spots. It is not necessary to draw the temper, as the hardening does not extend far below the surface.

Expanding Mandrels. There are several forms of expanding mandrels in common use. One form has a sleeve with a taper hole fitting on a mandrel that has a corresponding taper; the sleeve is split to allow it to expand as it is forced on the mandrel.

It is not advisable to give the mandrel very much taper, because a heavy cut with the pressure toward the small end would crowd the sleeve toward that end, thereby releasing the work. Ordinarily a taper of $\frac{1}{2}$ inch to the foot will give good results.

Fig. 63.

It is obvious that the range of adjustment for a sleeve as described is small, but sleeves of different diameters may be fitted to the same mandrel, the thickness of wall being increased to give the desired size. The diameter of the sleeve should be such that the work may enter without forcing, the tightening being accomplished by forcing or driving the sleeve toward the large end of the mandrel.

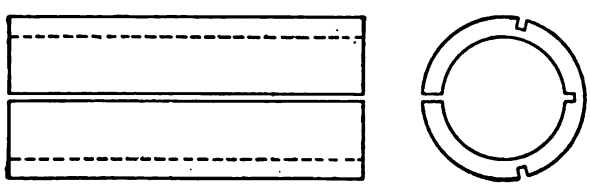


Fig. 64.

If a sleeve is required for a special sized hole, and is to be used but a few times, and through a limited range as to size, it may be made of cast iron. A hole is bored in it corresponding in size and taper to its mandrel; the hole should be made to allow the small end of the mandrel to go through and be flush with the end of the sleeve. The sleeve should be forced on the mandrel

and turned to size; the outside diameter should fit the hole in the piece to be machined when the sleeve is at the small end.

In order that the sleeve may be expanded it is split as shown in Fig. 64. This should be done in the milling machine, the sleeve being held by the ends in the vise and the cut made with a metal slitting saw. When the sleeves are intended for permanent

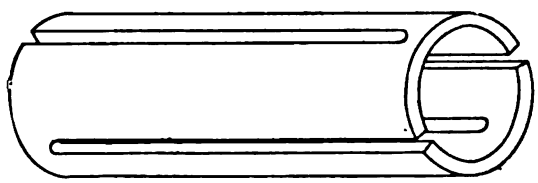


Fig. 65.

equipment it is good practice to make them of either machinery steel or tool steel,— if made of the former they may be case hardened, if of the latter they may be hardened and spring tempered. In either case the hole should be .010 inch small, and the outside diameter .020 to .025 inch large, and ground to size after hard-

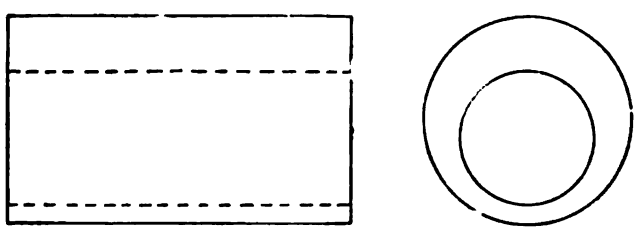


Fig. 66.

ening. A method of splitting the sleeve for a more uniform expansion is shown in Fig. 65; small sizes have four cuts for adjustment, while the larger sizes have six or eight.

On account of the peculiar construction of the sleeve shown in Fig. 65 it must be held while grinding the hole, so that it will not spring. To do this the sleeve may be placed in a hole in a collar and held by several drops of solder so placed as to hold it rigidly in position. In order that the solder may stick, the outside of the sleeve must be brightened. When soldered securely

the collar may be placed in the chuck on the grinding machine and the hole ground to the desired size, after which it may be heated to melt the solder, and the sleeve removed from the collar. It can then be placed on the mandrel and the outside diameter ground to the proper size.

Eccentric Arbors. Arbors are made eccentric in order that the outside of a piece of work may be made eccentric to the hole running through it, as shown in Fig. 66.

When making an eccentric arbor the general directions given for making mandrels may be followed, except that the centers should be quite small. The mandrel should be placed in a V block or in a pair of centers, and by means of a surface gauge, the needle of which has been set at the exact height of the center, a line may be drawn, as shown in Fig. 67, across each end of the mandrel. The mandrel may now be turned so that the line will be vertical; the point of the surface gauge may be raised to give the required amount of eccentricity, and a line, as shown in Fig. 68, scribed on each end. The ends should be prick punched where the lines intersect, and drilled and countersunk at this point.

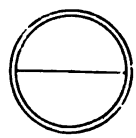


Fig. 67.

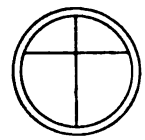


Fig. 68.

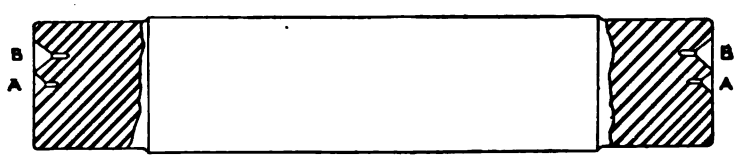


Fig. 69.

After hardening, both pairs of centers should be lapped to shape. The centers marked A A (Fig. 69) must be used when grinding the mandrel to size or in turning work which is to be concentric with the hole, while the centers B B are used when turning the eccentric parts. This method of laying off and drilling the eccentric center may not give the necessary accuracy; in such case a jig must be used in drilling the center holes. A suit-

able jig is shown in Fig. 70. The ends of the arbor must be turned to fit the hole A, Fig. 70, in the jig, which is a collar having a straight hole through it. A piece of steel, which is a forcing fit in this hole, has a hole the size of the centering drill laid off with the proper amount of eccentricity. This piece of steel is forced to the center of the collar, as shown at B. A straight line should be drawn across the collar and down the beveled edges, as shown at C. A line should now be scribed the entire length of the mandrel, which should be set to match the line on the jig, which may be secured in its proper position by means of the set screws.

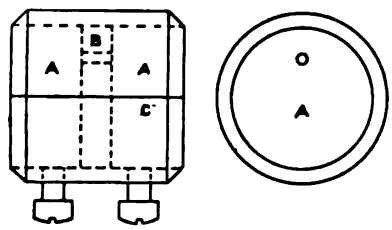


Fig. 70.

For machining a cylindrical piece having a hole through it to receive an arbor, and the faces of the piece not parallel, as shown in Fig. 71, it is well to use a mandrel having two sets of centers, as shown in Fig. 72, one of which, A A, are the regular centers, while the eccentric centers, B B, should be equidistant from the regular centers, but on opposite sides.

Milling Machine Arbors. Arbors for milling machines should be made from steel strong enough to resist (without twisting or springing) the strain caused by tightening the nut. When a limited number of arbors is made, tool steel is generally used; but for many milling machines, necessitating a great many arbors, a lower priced steel having the necessary stiffness is selected.

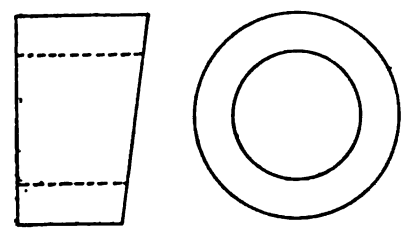


Fig. 71.

After centering and squaring the ends, a chip is turned the entire length of the piece, to remove all the outer surface. The ends D and C, Fig. 73, are next turned to size, and the tenon milled to the desired dimensions; when milling for the tenon, the

arbor should be held between centers, and the cutting done with an end mill of the form shown in Fig. 74; the circumference of the cutter, leaving the proper shape at end of tenon. The centers should be hardened, and the temper drawn to a straw color. If the projection on the end of the arbor at C, Fig. 73, is to be run in a socket in the tail block of a milling machine, it must be hardened the entire length, in which case the thread for the

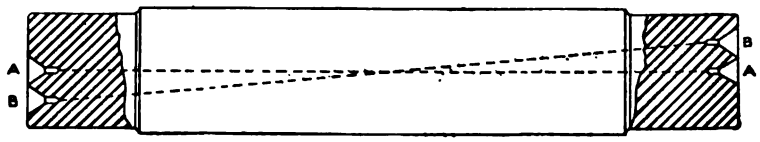


Fig. 72.

nut should be cut before hardening the end. If a lathe having a taper attachment is used, there is no particular method of procedure other than that the arbor should be roughed nearly to size before either the taper or straight end is finished. It will save time, however, if the straight end A, Fig. 73, is roughed first, then the taper B roughed and finished, after which the shoulder E and the straight part A may be turned to size and finished. If the projection C is to run in a socket, it should be turned .010 or .015 inch above finish size, and ground to the proper dimensions.

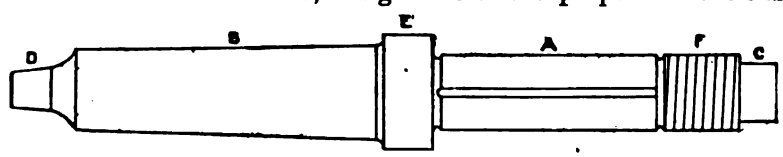


Fig. 73.

If it is necessary to use a lathe having no taper attachment, the necessary taper must be obtained by setting over the tail block. In this case it is better to turn and fit the taper first. If the taper were turned to finish size after finishing the straight part, the centers would become changed to a degree that would throw the arbor out of true. These instructions should be followed wherever a straight and taper surface are to be turned on the same piece of work, in a lathe having no other means of turning tapers except by setting over the tail block.

Milling machine arbors should have a spline slot cut the entire length of the part that is to receive the cutters; this can

best be done in a shaper. Before putting the arbor in the shaper vise a hole should be drilled close to the shoulder for the tool to run into; the drill used should be about $\frac{1}{32}$ inch larger in diameter than the thickness of the splining tool, and the hole drilled a trifle deeper than the slot to be cut. When the arbor is placed in the vise a piece of sheet brass or copper should be placed between the

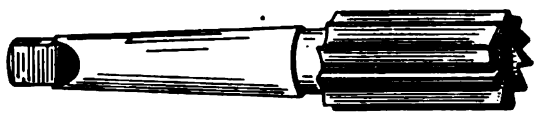


Fig. 74.

arbor and the vise jaws to prevent bruising the arbor.

Where *extreme* accuracy is required, it is advisable to leave the straight and taper parts a few thousandths of an inch above size and grind to size all over after the spline cut is taken.

The nut is usually made of machinery steel, case hardened. A bar of steel $\frac{1}{16}$ inch larger than finish size of nut is selected, and a piece $\frac{1}{16}$ inch larger than finish length is cut; it is then put in a chuck on the lathe, the hole drilled, and the thread cut; if no tap of the desired size is at hand the thread may be chased. If a tap can be obtained, the thread should be chased nearly to size and finished with the tap; before taking from the chuck the end of nut should be faced and the hole recessed to the depth of the thread for a distance of two threads. After taking from the chuck it should be placed on an arbor having a screw which fits the thread in the nut. The nut should be turned to size and length, and the two opposite sides milled to receive the wrench used in tightening. Fig. 75 gives two views of the nut. It should be made and case hardened before the thread is cut on the arbor, in order that the thread on the arbor may be made to fit the nut. Milling machine arbor nuts should fit the thread on the arbor in such a manner that they may be turned the entire length of the thread without the aid of a wrench, yet not be loose.

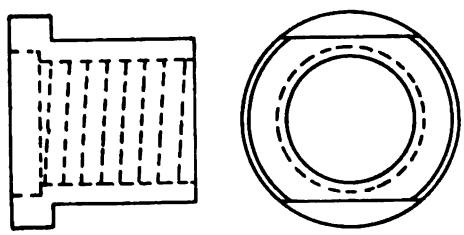


Fig. 75.

TAPS.

When making taps $\frac{1}{4}$ inch diameter and smaller, the threads are often cut with screw dies, of which there are two styles. The form of screw plate shown in Fig. 76 is termed a *jam die plate.* With this form the die is opened to allow the wire to pass through until it is even with the outside edge of the die, which is now forced into the wire by means of the adjusting screw A; the screw plate is revolved until a thread the desired length is cut. This operation is continued, the die being closed a trifle each

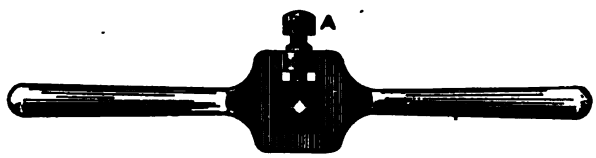


Fig. 76.

time until the desired size is obtained. The method taken of gauging the correct size varies in different shops; if only one is made, the tops of the threads are measured with a micrometer caliper; but for many taps of the same size, such as for sewing machines, guns and bicycles, a sizing die is used to give the threads an exact size. The threads are cut to within a few thousandths of an inch with the die plate, and finished with the sizing die. One form of sizing die is shown in Fig. 77.

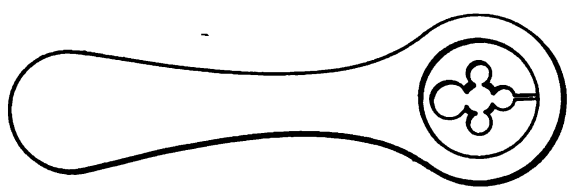


Fig. 77.

Where a great many taps of a size are cut, it is customary to use several dies of different sizes, one of which (the finishing die) is always made adjustable. The roughing dies may be made solid or adjustable, but the finishing must be adjustable for wear, or when it is found desirable to change the size of the taps. These dies are sometimes held in separate holders of the form shown in

Fig. 77, but a very convenient form of holder is shown in Fig. 78. If all the dies are in one holder they do not become scattered around the shop. When making many taps at a time, the work can be done better and cheaper if the wire is held in a chuck in a lathe. The die plate should be placed against a drill pad held in the tail spindle of the lathe, in order to insure starting the threads

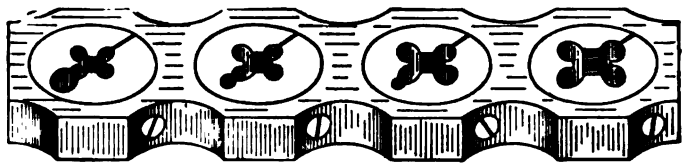


Fig. 78.

true. The largest die should of course be run on first, the second largest next and so on to the finish die.

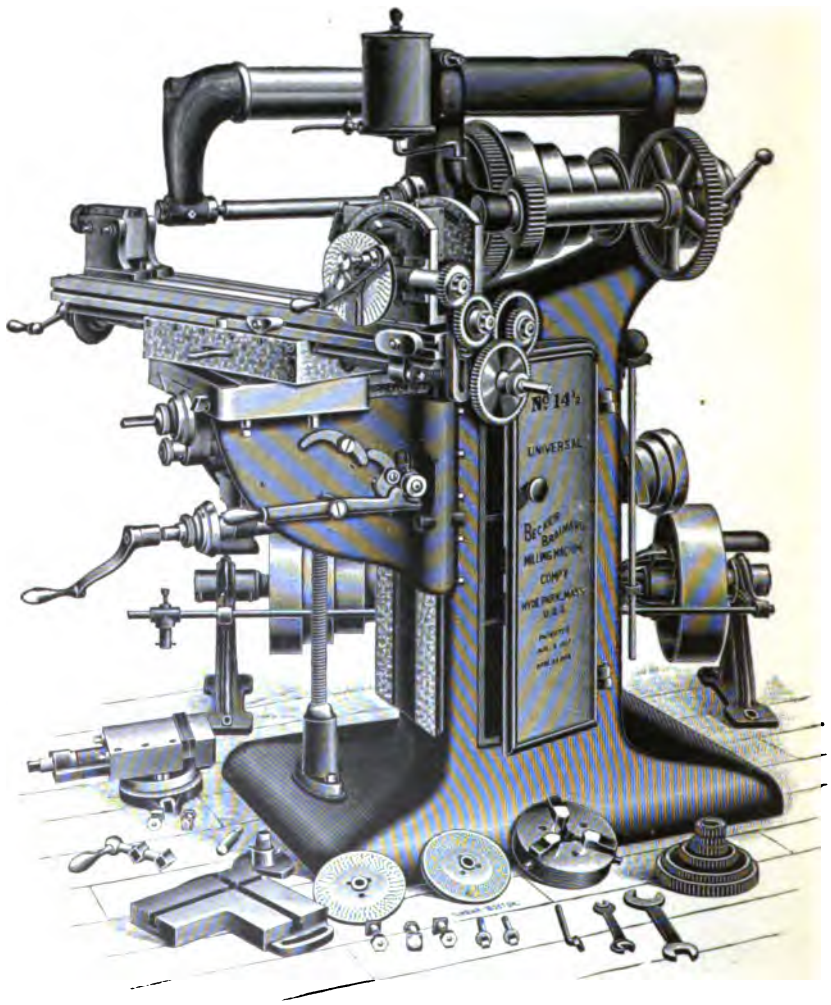
For taps up to and including $\frac{1}{4}$ inch diameter, it is customary to use drill rod. The taps should be chamferred for a distance of three or four threads, as shown at A, Fig. 79, in order that the point may enter the drilled hole.

Taps for general use around the shop are often made in sets of three; the first tap to enter the hole is called the taper tap,

Fig. 79.

because of tne long chamferring or taper. The second is known as the plug tap; this tap has the first two or three end threads chamferred, and is used when the screw is to go nearly to the bottom of the tapped hole. The bottoming tap is used when the thread is to go to the bottom of the hole being tapped; the end of this tap is not chamferred. See Fig. 80.

Taps larger than $\frac{1}{4}$ inch are made from tool steel. Taps $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter should be made of stock at least $\frac{1}{16}$ inch large; it should be centered quite accurately with a small drill, because a large center hole weakens the tap and increases the liability of its cracking when hardened. After taking a chip sufficiently deep to remove all the outer coating, it should be "box annealed" if possible.



VERTICAL MILLING MACHINE.

HAND TAPS.

Hand taps are intended for tapping holes by hand and are usually made in sets of three, as previously explained. After annealing, the shank should be turned to size and the square end milled for a wrench. The body should now be turned to size, and the thread cut. Before turning any of the parts to size or starting to cut the thread, be sure that the centers of the lathe are in good condition; the live center should run true, the dead center should fit the center gauge, and be in good shape.

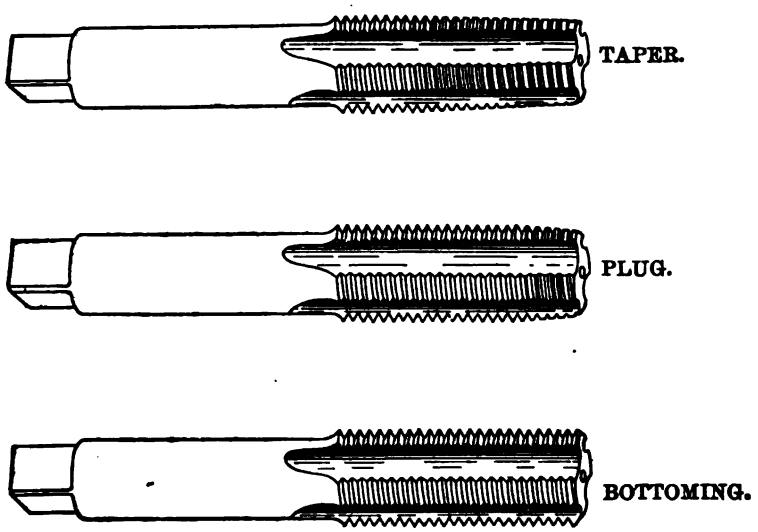


Fig. 80.

It is advisable to cut the tap slightly tapering, the thread being from .0005 to .001 inch smaller at the end toward the shank. This prevents the tap binding when slightly worn, yet it is not tapering enough to affect the accuracy of the thread. The thread tool should be an exact fit to the gauge, and placed in the tool post so that the top of the shank stands about level. The top of blade shown at A, Fig. 81, should be ground parallel with the top of the shank; the cutting point should be set at the exact height of the point of the head center. Many tool makers

consider it advisable to rough the thread nearly to size with a single point tool, finishing it with a chaser which may be held in the same holder. A chaser blade is shown in Fig. 82. After the thread is cut to size and the end chamferred, the tap is ready to be grooved in the milling machine. The tap is held between centers and the grooves cut with a cutter especially adapted to the size and style of tap. While the grooves should be cut with a milling machine cutter, it is possible to cut them in a planer or shaper, using a tool of the proper shape. Great care must be used not to stretch the tap by heavy chips, or by using a dull tool.

The grooves cut in taps are ordinarily termed flutes. When making taps for the market it is usual to cut four flutes in all taps

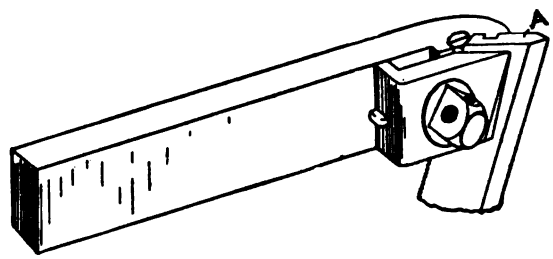


Fig. 81.

up to and including $2\frac{1}{2}$ inches diameter. But when taps are made in the shop where they are to be used, the number and shape of the grooves depend on the nature of the intended work. A tap that is to run through the work without any backing out, can have a different shaped flute from one that is to tap a deep hole in a piece of steel, where it is necessary to reverse the motion of the tap every two or three revolutions to break the chip, and also to allow the lubricant to reach the cutting lips.

While all taps up to and $2\frac{1}{2}$ inches diameter are usually given four straight flutes, spiral flutes are sometimes desirable, especially with small taps for some classes of work. With spiral flutes, it is generally necessary to cut a less number, and as taps are not ground after hardening, there is no objection to giving an odd number of teeth, as in case of a reamer. Three spiral flutes are often cut.

If a tap 1 inch in diameter, having four flutes of the regulation width, were used to tap tubing having thin walls, the tubing

between the lands would have a tendency to close into the flutes of the tap, which might break the tubing. In such a case there should be double the number of flutes, in order to provide enough lands to hold the tubing in shape. If the hole to be tapped has part of its circumference cut away as shown in Fig. 83, more than four lands are necessary.

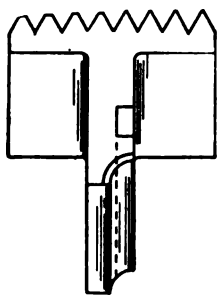


Fig. 82.

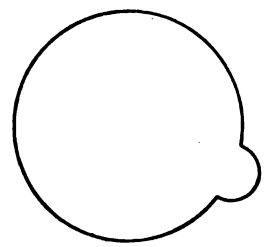


Fig. 83.

However, for general machine shop work four flutes work well in hand taps up to and including $2\frac{1}{2}$ inches diameter. For larger sizes, some tool makers advocate six flutes; others claim best results from taps having four flutes regardless of size. The class of work and the stock used in the individual shop must determine this.

Forms of Flutes. The most commonly used form of flute is that cut with a convex milling cutter (Fig. 84) for milling half circles. The advantages claimed for this form are: the flutes are of sufficient depth to provide for the chips, and yet leave the lands strong enough; and the form of the back of the land is such that the chips cannot be wedged between the land and the work when the motion of the tap is reversed. The form of groove made with this cutter is shown in Fig. 85. In order to support the tap when starting to cut, and to prevent cutting the hole large at the outer end, hand taps have their lands left wider (as shown at A, Fig. 85) than is the case with machine taps. If the forms

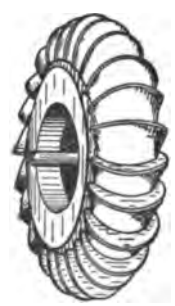


Fig. 84.

of cutter shown in Fig. 85 or Fig. 86 are used, the width of lands as shown at A may be one fourth the diameter of the tap. A Brown & Sharpe Tap and Reamer Cutter is shown in Fig. 86.

Fig. 87 shows a special form of cutter made by Brown and Sharpe. It does not make as deep a groove (Fig. 88) in proportion to the width as a Tap and Reamer Cutter.

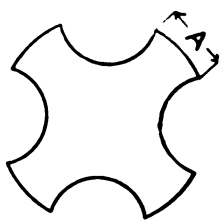


Fig. 85.

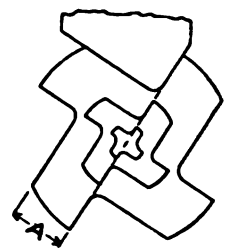


Fig. 86.

After cutting the grooves, the lands should be backed off to give the tap cutting edges; this is usually done with a file. Commence at the heel of the land, A Fig. 89, file the top of the land, and gradually approach the cutting edge, making sure that no stock is removed at that portion; simply bring it to a sharp edge. Enough should be filed off the heel A to make it cut readily, yet not enough to cause it to chatter. The size and number of threads per inch should be stamped on the shank of the tap. If it has a thread differing from that in general use in the shop, that should also be stamped on the shank, as U. S. S., if it is a United States Standard thread.

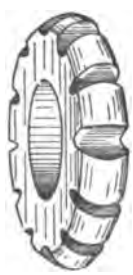


Fig. 87.

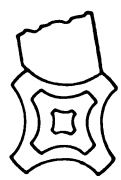


Fig. 88.

The following table gives the number of cutter for different diameters of taps when the form shown in Fig. 87 is used.

No.	1	Cutter	Cuts	Taps			to	$\frac{1}{4}$	inch	diameter.
"	2	"	"	"	from	$\frac{5}{32}$ inches	"	$\frac{1}{4}$	"	"
"	3	"	"	"	"	$\frac{9}{64}$ "	"	$\frac{3}{8}$	"	"
"	4	"	"	"	"	$\frac{7}{16}$ "	"	$\frac{5}{8}$	"	"
"	5	"	"	"	"	$\frac{11}{16}$ "	"	$\frac{7}{8}$	"	"
"	6	"	"	"	"	$\frac{13}{16}$ "	"	$1\frac{1}{4}$	"	"
"	7	"	"	"	"	$1\frac{5}{16}$ "	"	$1\frac{3}{4}$	"	"
"	8	"	"	"	"	$1\frac{11}{16}$ "	"	2	"	"

Hardening. If but a few taps are to be hardened at a time, it is customary to heat them in a gas jet or an open fire of charcoal or hard coal. It is advisable, however, to heat the taps gradually in a tube. They may be plunged one at a time into the bath a little above the threads. The tap should be worked up and down and around in the bath to prevent soft spots. Taps

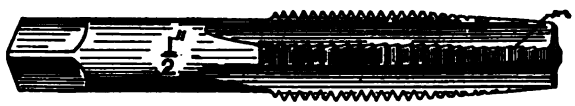


Fig. 89.

1 inch diameter and smaller should be left in the bath until cold; if larger they may be removed from the bath as soon as the singing noise ceases, and immediately plunged in oil and left until cold. For taps less than $\frac{1}{4}$ inch diameter, the citric acid bath will be found satisfactory; for larger taps use strong brine.

To have the tap retain as nearly as possible its size and correctness of pitch, use the "pack hardening" process. Run taps

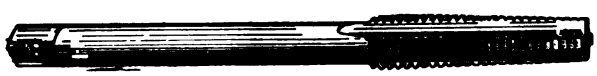


Fig. 90.

$\frac{1}{8}$ inch diameter and smaller, $\frac{1}{2}$ hour after they are red hot; taps $\frac{1}{8}$ to $\frac{1}{4}$ inch diameter, 1 hour; taps $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter, $1\frac{1}{4}$ hours; taps larger than one inch diameter, 2 hours. Harden in a bath of raw linseed oil.

It is advisable to grind the flutes of the taps with an emery wheel of the proper shape in order to brighten the surface, so that the color may be readily seen when drawing the temper. It also sharpens the cutting edges and breaks the burrs that have been thrown between the teeth when cutting the flutes. The temper should be drawn to a full straw color. Much more satisfactory results may be obtained by heating the taps in a kettle of oil, drawing the temper to a point from 460° to 500°, according to the size of the tap and the nature of the stock to be cut.

MACHINE TAPS.

As the name implies, machine taps are intended for screw machines, tapping machines, and lathes. They are held in chucks or collets by their shanks, and are supported firmly. Consequently the lands may be made narrower than those of hand taps to make them offer less surface to the work, thereby reducing the amount of frictional resistance. Also, they may be relieved between the teeth, by filing with a sharp cornered three square file, commencing at the heel of the tooth and filing nearly to the cutting edge.

Fig. 91.

It is not good practice to relieve the teeth very much because chips may be drawn between the work and the lands when backing out of the work. When taps are to be used in an automatic tapping machine without reverse motion the shanks are left long as shown in Fig. 90 in order that the nuts may pass over the thread and on to the shank. When this is full the tap is taken from the machine and the nuts removed; this can be readily done as they will pass over the end of the shank.

If a tap is to be used on nuts whose holes are punched to size, much better results are obtained by using a tap having five flutes, as shown in Fig. 91, instead of four. The uneven number of cutting edges reduce the liability of an imperfectly tapped hole, while the extra land furnishes additional support.

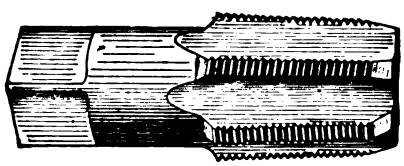


Fig. 92.

Taper Taps. When cutting the threads of a taper tap, Fig. 92, it is necessary to use a lathe having a taper attachment, as the pitch of the threads is not correct if the taper is obtained by setting over the tail stock. Like machine taps, the teeth of a taper must be relieved back of the cutting edge.

In setting the threading tool for cutting taper taps, care

should be taken that it is square with the axis of the tap, rather than square with the taper sides.

Screw Die Hobs. Die hobs are finish taps for sizing the thread in screw cutting dies. The several flutes are narrower than those of an ordinary tap and the lands are correspondingly wider. The tap shown in Fig. 93 has eight flutes. The increased number and broader lands support the tap while running through dies whose clearance holes are drilled, in order to remove burrs thrown in the threads when drilling. It is customary to give screw die hobs six to ten flutes.

When hobs are used for solid dies they must be of exact size. When intended for tapping adjustable dies, such as are ordinarily used for cutting threads in screw machine work, the hobs are made

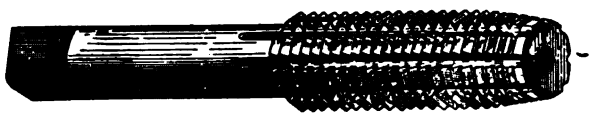


Fig. 93.

from .003 to .005 inch above the size of the screw to be cut. The extra size gives relief to the threads of the die.

While it is generally considered advisable to run one or more taps through a die before the hob, some tool makers consider it better to make a hob that will do all the cutting, claiming that

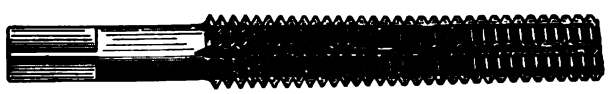


Fig. 94.

no two taps can be made and hardened so that the pitch will be exactly the same. In such cases a hob (Fig. 94) is made that will cut a full thread by passing through the die.

Some manufacturers cut the thread tapering for about three-quarters of the entire length of the thread, leaving the balance straight for use in sizing the die. Others cut the thread straight and taper the outside of the thread for three-quarters its entire length. If the threads are cut tapering, they must be relieved back of the cutting edges, as already described.

ADJUSTABLE TAPS.

A solid tap made to cut to exact size, having no leeway for wear, soon becomes too small. This is overcome by making a tap that may be adjusted from time to time. Another reason for making taps adjustable is that the holes may be tapped to fit hardened screws which vary in size on account of having been hardened.

Probably the most common form of adjustable tap is the one shown in Fig. 95. This tap is made in one piece, and then split. It has some means of adjustment whereby the tap may be expanded or contracted through a limited range. This may be accomplished by using a taper bodied screw. The hole to receive the screw should be drilled, tapped and taper reamed, before the

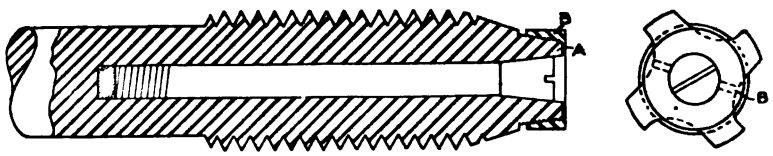


Fig. 95.

tap is turned to size. The thread should then be cut and the taper thread cut on the end at A. There is less tendency to spring when the tap is hardened if the projection shown in Fig. 96 is provided; this may be ground off after the tap is hardened and tempered. After cutting the flutes, the tap may be split in the milling machine using a metal slitting saw; the tap should be held between centers. It is split on two opposite sides, as shown at B, Fig. 95. The splitting should not go to the end of the projection.

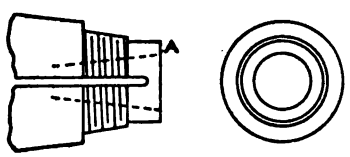


Fig. 96.

For hardening taps "Pack Hardening" is the best method. But, if it is impossible to use this method, heat the tap very carefully in a muffler furnace, or in a tube, having previously plugged the hole for the adjusting screw with fire-clay mixed with water to the consistency of dough. When the tap is heated to the

proper degree it should be dipped in a bath of luke-warm brine, and worked up and down rapidly. After hardening, it should be ground in the flutes, and the temper drawn to a full straw color. The projection on the end may be ground off, the taper screw inserted, and the locking nut B, Fig. 95, screwed to place. This nut has a taper thread cut inside to correspond with the thread on the tap at A, Fig. 95. It will be found necessary to cut the taper thread on the tap and in the nut by means of the taper attachment.

Inserted Blade Taps. The first cost of an inserted blade

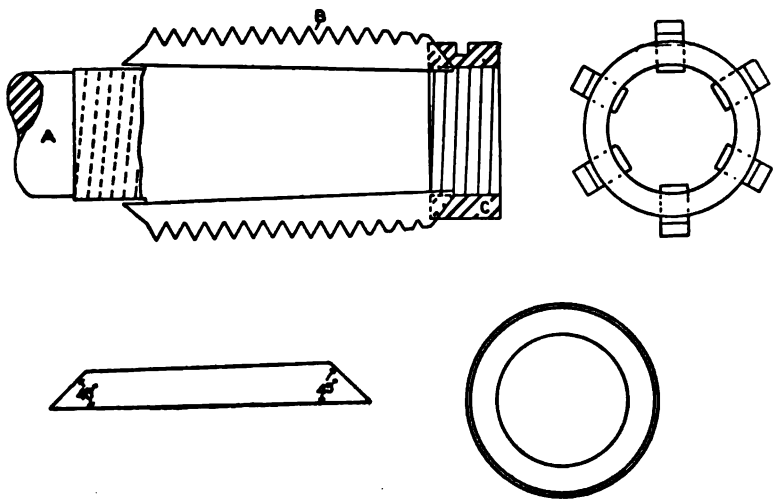


Fig. 97.

tap may not be much less than that of a solid tap of the same size, yet on account of the comparatively small cost of new blades which can be inserted in the same body, or holder, when the first set becomes worn, this form is very valuable for taps larger than $1\frac{1}{2}$ inches diameter. The tap shown in Fig. 97 may also be used as an adjustable tap. The shank or holder A is made of machinery steel, and the adjusting collars C C are beveled on the inside at one end at an angle corresponding to the angle on the ends of the blades. An angle of 45° will be found satisfactory.

After turning the body, or holder to size, and cutting the threads to receive the nuts, the slots for the blades may be milled;

these should be cut deeper at the cutting end in order that any change in the location of the blades may alter the size of the tap. A taper of $\frac{1}{16}$ inch in three inches is ample. If the slots are milled on the universal milling machine, and the tap held in the universal centers the spiral head may be depressed sufficiently to give the desired angle. If a pair of centers of the form shown in Fig. 98 are used they may be held in the milling machine vise at

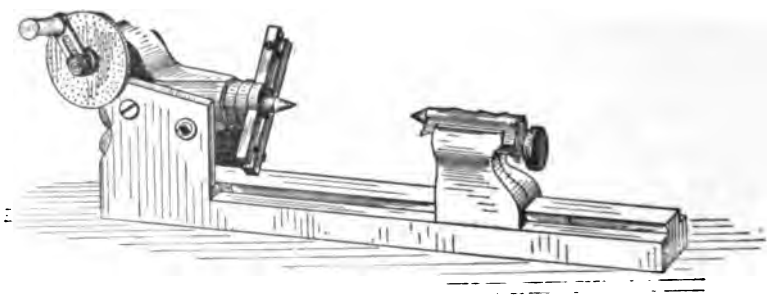


Fig. 98.

the desired angle. The milling cutter should be set about $\frac{1}{32}$ inch ahead of the center in order that the face of the blade may be milled enough to take any inequality in the teeth at the cutting face of the blade occasioned by the thread tool striking the face

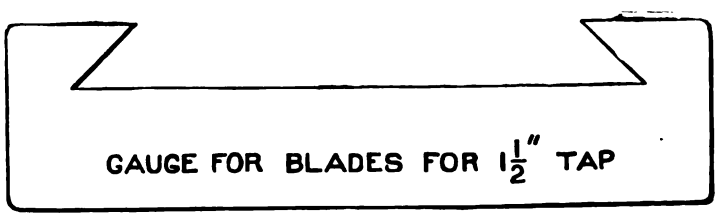


Fig. 99.

when it starts to cut. The amount milled from the face should be just enough to leave the cutting face radial. The blades should be of an exact length and should fit accurately in the slots. A gauge of the form shown in Fig. 99 will insure uniform length. After the blades have been carefully fitted to the slots and to the gauge, they may be inserted in the holder and secured by the nuts as shown in Fig. 97. The outside diameter is then turned about

.005 inch smaller than the size the tap is to cut and the threads very carefully cut; after which the face of the blades may be milled as explained, the cutting end chamferred, and the necessary amount of clearance given the cutting edges by filing. The blades are now ready for hardening.

When hardening, the blades should be subjected to a slow heat in a muffler furnace, or a tube. When a blade reaches a low uniform red heat, it should be immersed in a bath of luke-warm water or brine, and worked up and down to insure uniform results. After hardening it may be brightened and drawn to a deep straw color. It is well to place all the blades in a pan having a long handle, as shown in Fig. 100. Coarse sand to a depth of about 1½

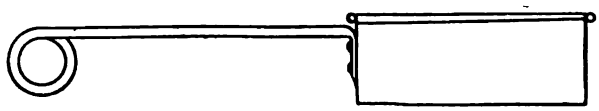


Fig. 100.

inches may be placed in the bottom of the pan with the blades. The pan should be placed over a bright fire and shaken carefully so that the teeth will not be dulled by striking the other hardened blades, while the sand and the blades are heating. The motion causes it to heat uniformly and the sand keeps the surface of the work bright so that the temper colors may be readily seen. This method of drawing temper will be found very satisfactory on many classes of work. It is also used extensively when coloring pieces by heat where a great many pieces are to be colored uniformly.

Square Thread Taps. Although the square thread is not as extensively used as formerly, having given place in many shops to the "Acme Standard," yet it is sometimes necessary to make taps for this form.

Steel should be selected sufficiently large and the decarbonized portion removed; the shank should be turned to size. The square should be milled for a wrench and the size and number of threads per inch stamped on the shank. The cutting end of the tap should be turned to size, the necessary amount of taper given the tap and then the threads cut

The tool used for cutting square threads is similar in form to a cutting-off (parting) tool except for its angle of side rake; it should be made of the proper thickness at the point but should be somewhat narrower back of the cutting end, as shown in Fig. 101, in order that it may clear when cutting.

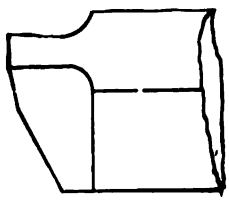


Fig. 101.

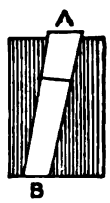


Fig. 102.

The thickness of the cutting end should be one half the distance from the edge of one thread to the corresponding edge of the next thread. For a square thread of 2 pitch, the land and space together would be $\frac{1}{2}$ inch, while the land and space would each be $\frac{1}{4}$ inch wide. The point of the tool would be $\frac{1}{4}$ inch thick.

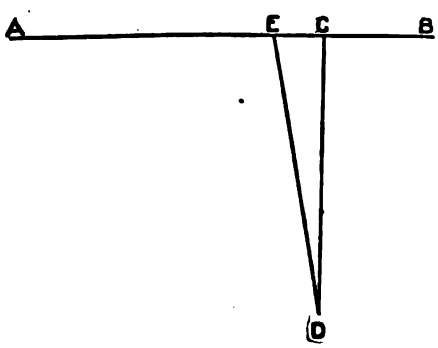


Fig. 103.

The sides of the tools from A to B, Fig. 102, must be inclined to the body as shown, the amount of the inclination depending upon the pitch of the thread and diameter of the tap to be cut. It may be determined, however, by the method shown in Fig. 103. Draw the line A B, and at right angles to it draw C D, whose length must be equal to the circumference of the thread to be cut, measured at the bottom or root of the thread. On A B lay off from the point C a distance E C equal to the pitch of the thread to be cut. Then draw the line D E, which will represent the angle of the side of the thread; the angle of the side of the cutting tool must be sufficiently greater to give the

necessary clearance. It is advisable to cut the thread with a tool somewhat narrower than the required width at first, and finish with a tool of the proper thickness.

Square thread taps may be fluted according to directions given for V thread taps. If a tap is intended to cut a full thread, it must be well backed off, in order to avoid the necessity of using so much force that the tap would be broken. When a tap is to

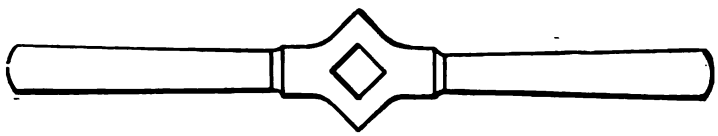


Fig. 104.

be used to size a hole whose thread has been cut by a smaller tap, very little clearance is necessary.

Tap Wrenches. When taps are used whose squares are all of a size, a solid tap wrench may be made, as shown in Fig. 104. This wrench is forged nearly to shape, the handles turned to size

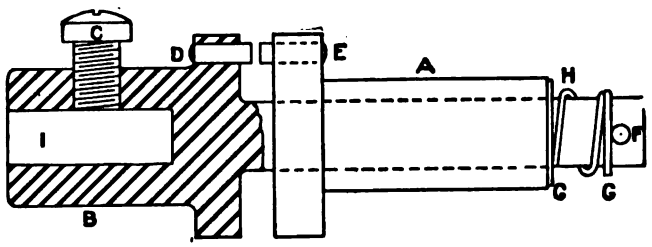


Fig. 105.

in the lathe, and the square hole in the center drilled and filed.

Releasing Tap Holders. When holes are to be tapped to a uniform depth in a screw machine or turret lathe, a tap holder is used which automatically releases the tap when it reaches the required depth. A very common form which gives excellent results when properly made and adjusted is shown in Fig. 105. It consists essentially of a sleeve A, which fits the tool holes in the turret of the screw machine, and the tap holder B, which fits the hole in the sleeve in such a manner as to slide longitudinally. The sleeve A should be made of tool steel if of a diameter that

makes the wall around the hole thin; the hole should be drilled and reamed to size, and the outside turned to size. The portion of the sleeve which enters the hole in the turret should be a snug fit. The tap holder B should be made of tool steel, or of a grade of machinery steel possessing great stiffness and good wearing qualities. After roughing out to sizes somewhat larger than finish, the end which is to hold the tap may be turned to size and the (stem) end which is to run in the sleeve may be fitted, after which the hole I, to receive the tap may be made of a convenient size. In order that the hole may be perfectly concentric with the holder it will be necessary to run the large end of the holder in the steady rest of the lathe; the opposite end should be fastened against the head center of the lathe in such a manner that the stem runs perfectly true. With work of this nature, the head center of the lathe must be in good condition and run true.

After the hole has been drilled somewhat smaller than finish size, it is necessary to true the hole with a boring tool; the hole should be bored to within .010 inch of finish size, after which it may be reamed with a rose reamer. Before reaming, however, the outside edge of the hole should be chamferred to the shape of the point or cutting end of reamer, to avoid any possibility of the reamer running. Some tool makers never ream a hole of this nature if it can be avoided, always boring to size with a tool that makes a smooth cut; but if extreme care is used, results good enough for a tool of this character may be obtained if the holes are finished to size with a reamer.

THREAD CUTTING DIES.

The size of a die is always denoted by the diameter of screw it will cut; a die that will cut a $\frac{1}{2}$ inch screw is called a $\frac{1}{2}$ inch die, irrespective of the outside diameter of the die itself.

Thread cutting dies are made solid or adjustable. Solid dies are used when extreme accuracy is not required. They are comparatively inexpensive, and may be used to advantage as a roughing die when an adjustable die is used for finishing. Owing to the tendency of dies to change their sizes when hardened, and to the fact that there is no provision for wear, they cannot be used

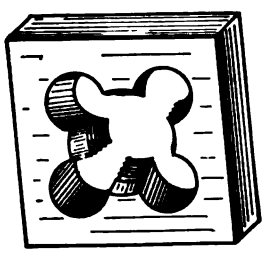


Fig 106.

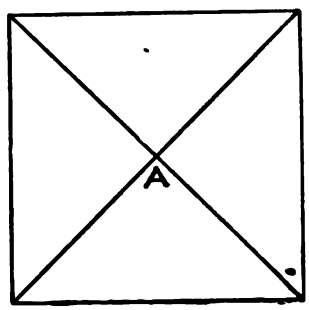


Fig 107.

where work must be made to gauge. They are extensively used in cutting threads on bolts, and for this class of work are made square, as shown in Fig. 106.

In making a square die the blank may be machined to thickness and to size on the square edges. One of the flat surfaces should be coated with blue vitriol, or the blank may be heated until it shows a distinct brown or blue color. The center may be found by scribing lines across corners, as shown in Fig. 107. It should be prick punched at A where the lines intersect. The die blank may be clamped to the face plate of a lathe and made to run true by means of the center indicator. If there is no tap of the proper size, and only one die is to be made, the thread may be

cut with an inside threading tool, provided the hole is of sufficient size; if not, a tap must be made. If the thread is cut with a threading tool, the size must be determined by means of a male gauge, which may be a screw of the proper size. After threading, the hole should be chamferred to a depth of three to four threads, the amount depending on the pitch of the thread; a fine pitch not requiring as many threads chamferred as a coarse pitch. The chamferring should not be much larger on the face of the die than the diameter of the screw to be cut. Figs. 108 and 109 show two views of a die chamferred and relieved on the cutting edges. The chamferring may be done with a countersink or taper reamer of the proper angle. In the absence of such a cutter, a tool held in the tool post of the lathe may be used.

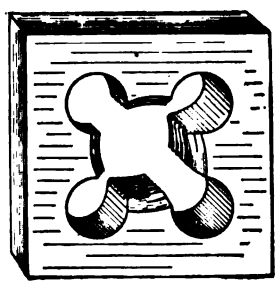


Fig. 108.

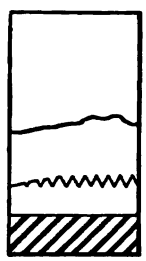


Fig. 109.

Most manufacturers making dies for the market give four cutting edges to all sizes up to and including four inches. When dies are made in the shop where they are to be used, custom varies. Some tool makers advocate three cutting edges for all dies smaller than $\frac{1}{4}$ inch, and five or more cutting edges for dies above two inches. The objection to more cutting edges than are absolutely needed on large dies is the increase in the cost of making.

When making dies for threading tubing, or for work where part of the circumference is cut away, it is better to give them a greater number of cutting edges than would otherwise be the case.

Rake of Cutting Edges. For general shop work, where the dies are to be used for all kinds of stock, it is advisable to make the cutting edges radial as shown in Fig. 110, the cutting edges

A A A A all pointing to the center. For cutting brass castings, the cutting edges should have a slight negative rake as shown in Fig. 111, the cutting edges A A A A all pointing back of the center.

Clearance Holes. After threading and countersinking (chamferring), screw in a piece of steel threaded to fit the die, and face it off flush. Lay out the centers of the clearance holes

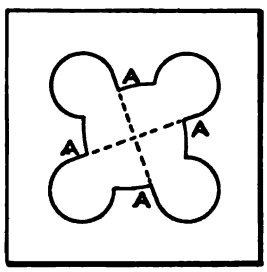


Fig. 110.

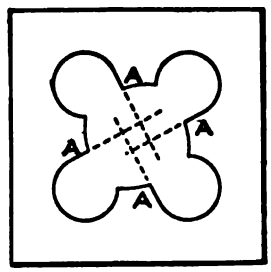


Fig. 111.

on the back of the die, and drill with a small drill the size of the pilot of a counterbore whose body will cut the right size for the clearance hole. The centers of these holes for dies having four cutting edges, and from $\frac{3}{8}$ to $\frac{3}{4}$ inch may be the intersections of a circle having a diameter equal to the diameter of the screw to be cut, and lines drawn across the corners as shown in Fig. 112. Prick punch these points. For a die having four clearance holes whose centers are laid out as shown in Fig. 112, it is customary to make the clearance holes one half the size of the die; that is the size of clearance holes in a $\frac{1}{2}$ inch die would be $\frac{1}{4}$ inch. The width A, Fig. 113, of the top of the lands should be about $\frac{1}{16}$ of the circumference of the screw to be cut. The diameter of clearance holes given does not apply to dies smaller or larger than sizes given ($\frac{3}{8}$ to $\frac{3}{4}$ inch), especially if the dies are to be used in the screw machine, as the clearance hole not only

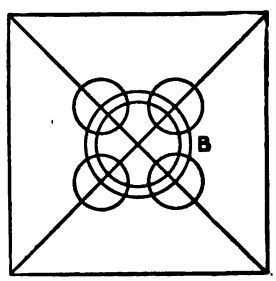


Fig. 112.

provides a cutting edge, but also makes a convenient place for the chips; if these are so small that the oil cannot wash the chips out, the chips clog the holes and tear the thread.

For small dies the clearance holes are of a size that allows the chips to collect in the holes without tearing the threads, and are located a greater distance from the center of the die, in order to give sufficient strength to the lands. The desired shape and thickness may be given the sides of the lands by filing. When it is considered advisable to give screw dies above $\frac{3}{4}$ inch larger clearance holes than the size mentioned, they may be located at a distance from the center of the die that will give the desired thickness to the land.

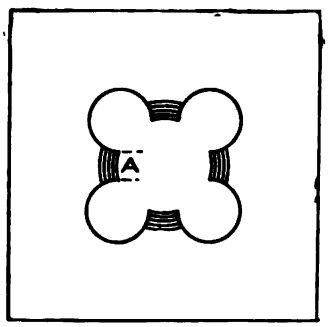


Fig. 113.

For screw machine and turret lathe work, dies are generally made circular, and as holders for dies are part of the equipment of every shop having screw machines, the dies should be made to fit these holders; but it is not considered good practice to make the diameter of dies less than $2\frac{1}{2}$ times the diameter of the screw to be cut, and the thickness of the die may be $1\frac{1}{4}$ times the diameter of the screw.

ADJUSTABLE DIES.

While round dies for screw machine work may be made solid for roughing out a thread that is to be finished by another die, the finish die should be made adjustable in order that the desired size may be obtained. When making adjustable dies the same general instructions may be followed that are given for making solid dies, except that some provision must be made for adjustment. This is done by splitting the dies at one side as shown at A in Fig. 114. In order that the die may not spring out of shape in hardening, it is advisable to cut the slot from the center of the die, leaving a thin margin as shown at A, Fig. 115; after the die is hardened this may be cut away with a beveled emery wheel. If the thickness at B is too great to allow the die to close readily when ad-

justed to size, the hole shown may be drilled and connected with the clearance hole by means of a saw cut.

If many round dies of the same diameter are to be made it is economical to have a holder with a shank which fits the hole in the spindle of the lathe; the opposite end should be made to

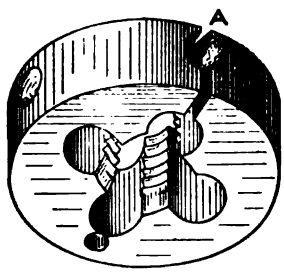


Fig. 114.

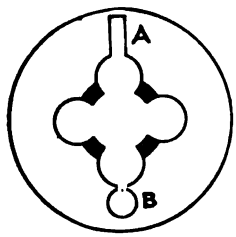


Fig. 115.

receive the die blanks which should be turned to fit the die holder in the screw machine. Fig. 116 shows the holder to be used in the lathe. A represents a die blank in the holder; B is the shank which fits in the spindle of the lathe; C is a recess in the holder to provide for the projection left on the blank when it is cut from

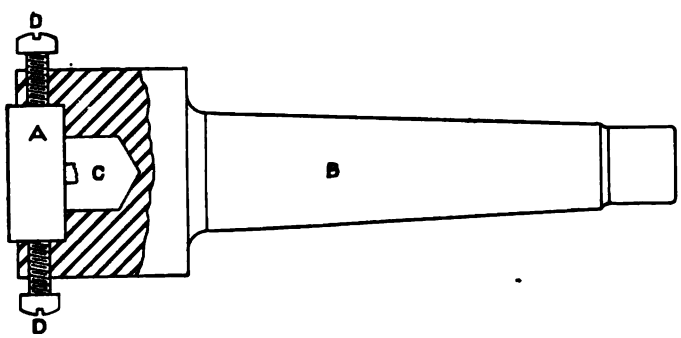


Fig. 116.

the bar and also provide an opening to receive the drill and tap after they run through the die. After the blank is placed in the holder and secured in position by the screw D, the outer surface may be faced smooth and true with the circumference, after which it may be reversed and the opposite side finished to the proper thickness. The die may now be drilled and tapped. Be-

fore drilling, the die should be carefully centered in the lathe; to insure a full thread in the die, a drill a few thousandths of an inch smaller than tap size should be used in drilling, after which a reamer of the proper size may be run through. When tapping the thread, it is advisable to use two or three taps of different sizes; the finish tap should be the size of the desired hole in the die, and should be of the form known as screw die hob. Where several taps are used in tapping a die, there should be some difference in the diameter so that any inequality in the shape or pitch of the thread may be removed by the larger tap, otherwise imperfect threads will result. For instance if three taps are to be used for a ¼ inch die, the first tap may be .230 inch diameter; the second .240 inch diameter, and the finish tap .250 inch diameter if the die is to be solid. If it is to be an adjustable die, the

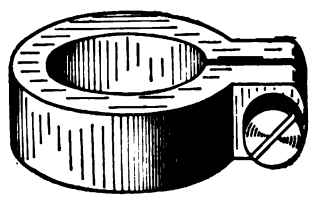


Fig. 117.

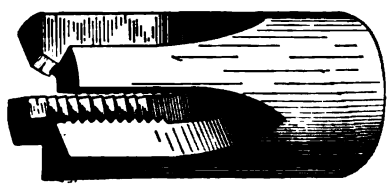


Fig. 118.

finish tap should be .253 inch diameter in order to furnish clearance to the lands when it is closed to .250 inch.

Dies should be heated very slowly for hardening, either in a muffler furnace, or in some receptacle to protect it from the action of the fire. When the die is heated to a uniform low red it may be immersed in a bath of lukewarm brine and worked back and forth to insure hardening the threads. The temper should be drawn to a full straw color. If it is an adjustable die the portion marked B_1, Fig. 115, should be drawn to a blue color in order that it may spring without breaking; this may be done by placing this portion of the die on a red hot iron plate, or the jaws of a heavy pair of tongs may be heated red hot, the die may be grasped in the tongs and held until the desired color appears. Do not allow the blue color to extend to the threads or they will be too soft. When the desired color has been obtained the die may be dropped into oil to prevent drawing the temper more than is desired.

Spring Screw-threading Dies. This form of die is adjusted by means of the clamp collar shown in Fig. 117; the die is shown in Fig. 118. In some shops it is the only form of screw-threading die used for screw machine work. When so used it should be fitted to one of the holders on hand, provided there be one of the proper size.

Average proportions of spring dies are given in the following table; these sizes are used by a manufacturing concern using a great many screw-threading dies of this description. It is not necessary to follow the proportions given, as they are intended only as a guide, and may be changed to suit circumstances. All dimensions are in inches.

SPRING SCREW-THREADING DIES.

Size of Screw.	Outside Diameter.	Length.
$\frac{1}{8}$ to $\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$
$\frac{1}{4}$ to $\frac{3}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$
$\frac{3}{8}$ to $\frac{1}{2}$	1	2
$\frac{1}{2}$ to $\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$
$\frac{3}{4}$ to 1	$1\frac{5}{8}$	$2\frac{1}{2}$
1 to $1\frac{1}{4}$	2	3
$1\frac{1}{4}$ to $1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{2}$
$1\frac{1}{2}$ to 2	$3\frac{1}{4}$	4

For uniform and well-finished threads, two dies should be used, one for roughing, and one for finishing.

Where many dies of a size are made it is best to have a holder with a shank fitting the center hole of some lathe. The stock can be machined to size and cut to length. The clearance hole in the back of the die should be first drilled somewhat larger than the diameter of the screw to be cut. For dies up to and including $\frac{1}{8}$ inch the clearance holes should be $\frac{1}{32}$ inch large; for dies $\frac{1}{8}$ to $\frac{1}{4}$ inch it should be $\frac{3}{64}$ inch large; for dies $\frac{1}{2}$ inch and over, it should be from $\frac{1}{16}$ to $\frac{1}{8}$ inch large. After drilling the clearance hole, the die should be reversed in the holder, and drilled and tapped the same as a round die, using a hob to finish the

threads to size. For general work, the die should have four cutting edges making the lands about one-sixteenth the circumference of the screw to be cut. Chamfer about three threads. The length of the threaded portion of the die should not exceed one and one-quarter times the diameter of the screw to be cut. To produce the cutting edges, use a 45° double angle milling cutter shown in Fig. 119; this cutter should be of sufficiently large diameter to produce a cut as shown in Fig. 120.

The chamferred edges should be relieved and the cutting edges finished with a fine file. Stamp the size and number of threads on the back end of the die as shown in Fig. 120 and then harden. The die should be heated in a tube and hardened in a jet of water coming up from the bottom of a tank in order that the water may enter the threaded portion. It should be hardened a little farther up than the length of the thread, moving up and down in the bath to prevent a water line; the temper should be drawn to a full straw color.

Fig. 119.

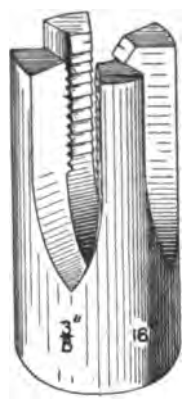


Fig. 120.

Where many clamp collars are used, castings of malleable iron or gun metal may be made from a pattern; the hole should be cored to within $\frac{1}{16}$ inch of finish size. The hole may then be drilled and reamed. When the screw hole has been drilled and tapped and the collar split, it is ready to use. If the surfaces are finished it adds very materially to the cost.

Die Holders. When cutting threads in screw machines and turret lathes, dies are held in die holders which are constructed in two parts as shown in Fig. 121. The shank A fits the hole in the turret, while the die holder B has a stem that fits the hole in the shank. While the die is cutting, the pins D and C are engaged, thus preventing the holder B from turning. When the turret slide of the screw machine has traveled to its limit, the holder is drawn out of the shank until the machine is reversed

when the pins engage on their opposite sides. A pin is put through the stem of the holder at E; this strikes the end of shank just at the time the pins D and C become disengaged.

Both shank and body may be made of machinery steel; the shank may be finished to size except the portion marked A, which should be left .010 inch large for grinding. The front end of the hole should be rounded as shown in Fig. 121, to allow the fillet in the shoulder of the stem to enter. This fillet is left for strength. The pin hole should be drilled and reamed. When the holders are to take dies not over $\frac{1}{8}$ inch in size, this pin hole may be $\frac{3}{16}$ inch diameter; from $\frac{1}{8}$ to $\frac{5}{16}$ in size, $\frac{1}{4}$ inch diameter. As the dies

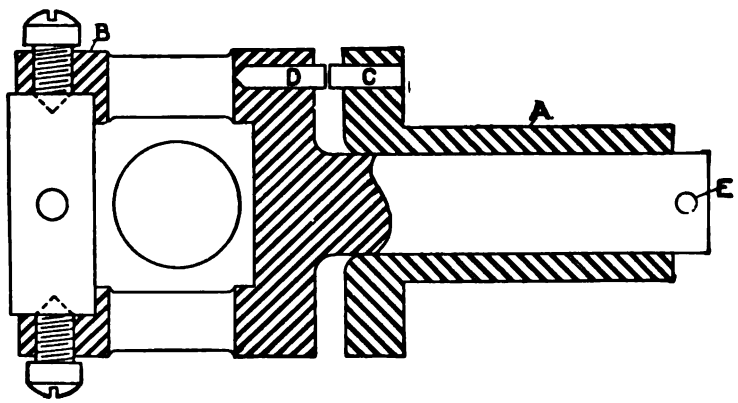


Fig. 121.

increase in size the pin must increase proportionately. The shank may be case-hardened in a mixture of granulated charred leather and charcoal; it should run about two hours and then be dipped in a bath of oil. The hole should be lapped straight and true. The outside ground to fit the hole in the turret. The pin C should be of tool steel hardened and drawn to a blue color, and forced into place.

The holder B may be made from a forging, or turned from a solid piece. After roughing to size somewhat larger than finish, the stem may be turned and fitted to the hole in the shank; it should turn *freely* in the shank. The larger portion (or body) should now be turned to size. This should be run in the steady rest, and the end drilled and bored for the die and for clearance

back of the die as shown in Fig. 121. Three or four large holes should be drilled into the clearance hole in order that the chips and oil may find a way of escape, thus preventing injury to the threads of a screw long enough to reach through the die when being threaded.

Screw holes should be drilled and tapped as shown in Fig. 121; the screws are to hold the die in position in the holder and also to adjust to size dies that are split. The stem may be placed in the shank and the pin hole transferred through the pin hole in

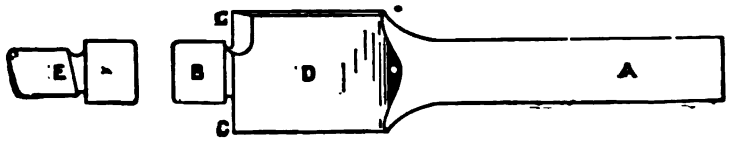


Fig. 122.

the shank into the body; this should be done before the pin C is pressed into place. The pin D should be hardened the same as C.

The pin hole for the pin E may be drilled in a location that allows C and D to become disengaged and yet have no play between the two

COUNTERBORES.

Counterbores are used for enlarging a hole without changing its relative position. For a *hurry up* job and for a small number of holes, it is advisable to make as cheap a form as is consistent with the work to be done. Probably the cheapest counterbore that will do satisfactory work is the flat form shown in Fig. 122. This can be forged to require but little machine work. After forging, turn to size; finish the shank A and pilot B with a fine file before taking from the lathe. The cutting edges C C should be faced true and smooth. The necking between the pilot and the body should be cut with a tool having the corners slightly rounded to decrease the liability of cracking when the counterbore is hardened. The flat sides D of the body may be finish filed; the edges should be draw-filed, removing more stock on the back than on the cutting edge to prevent binding. File the cutting edges C C for clearance, as shown at E, Fig. 122. The

pilot and the body should be hard the entire length or they will wear and rough up and consequently cannot cut a smooth hole; draw the temper to a full straw color. Unless intended for *accurate* work it need not be ground.

For permanent equipment, counterbores are usually made with four cutting edges as shown in Fig. 123 and Fig. 124. Fig. 123 representing a taper shank counterbore for a taper collect, while Fig. 124 has a straight shank to be used in a chuck, or collet having a straight hole the size of the shank.

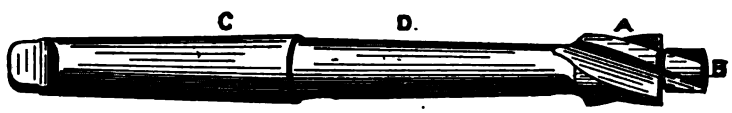


Fig. 123.

Counterbores for screw holes are usually made in sets of three, one for the head of the screw with pilot (or guide) of body size, one for head with pilot of tap drill size, and one to enlarge a tap drill hole to body size. The following instructions apply to counterbores with either straight or taper shanks. Take stock somewhat larger than finish size of counterbore.

Fig. 124.

Turn a roughing chip all over the piece; turn the necked portion between the shank and body to size and stamp size of counterbore and pilot as shown in Fig. 124; turn shank C, body A, and pilot B .015 to .020 inch above finish sizes, to allow for grinding. In the case of the taper shank counterbore shown in Fig. 123 the tennon should be milled. The counterbore is now ready to have the grooves milled to form the cutting edges. One method is to cut them with a right-hand spiral of from 10° to 15°; the other method is to cut the grooves straight. The former has he effect of running chips back from the cutting edges and works

very well on wrought iron and steel, while the latter method is considered more satisfactory for brass and cast iron and also works well on wrought iron and steel. The cutting edges are given clearance by filing, as shown at A in Fig. 125. If the counterbore is to be used for brass it is necessary to give clearance to the lands also as shown at A A A A, Fig. 126.

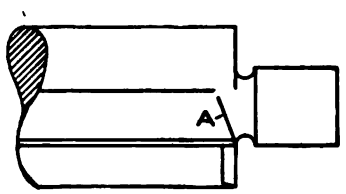


Fig. 125.

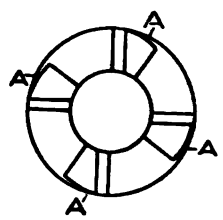


Fig. 126.

When centering counterbores or any tools whose centers are not to be used after the tool is finished, the drill should be small and the countersinking no larger than is necessary for good results in machining. If large centers should, by accident, be put in the ends, the one on the end to be hardened should be filled with fire clay moistened with water to the consistency of dough, or with graphite mixed with oil; this prevents steam forming in the

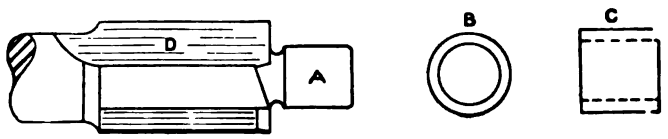


Fig. 127.

hole and cracking the tool when dipped in the bath. If the piece is to be heated in lead, the filling should be dried thoroughly before immersing in the red-hot lead.

Solid counterbores can be used with holes larger than the pilot by forcing a sleeve over it as shown in Fig. 127. B and C are two views of the sleeve which is to be forced on to pilot A. After hardening, the counterbore may be ground to size on the shank, body and pilot; the shank should be ground first as the length is greater, and in the case of a counterbore having a

straight shank the grinder may be adjusted to perfect alignment by measurement.

Two lipped counterbores are sharpened by grinding on the flat faces marked D, Fig. 122. Grind a four-lipped counterbore on the flat side of the groove as D in Fig. 127.

Facing Tool with Inserted Cutter. Where a limited number of holes are to be counterbored, the tool shown in Fig. 128

Fig. 128.

may be made. All that is necessary in making this tool is a piece of stock A, the size of the hole to be counterbored and a piece of drill rod for the cutter B; this may be filed to a cutting edge, hardened and driven in place. If accuracy is essential, a piece of drill rod must be cut off somewhat longer than the diameter of the required hole; it should be driven into the hole in the bar leaving an equal length on each side. It may be turned to the correct diameter and filed to shape. If several cutters are to be used in the same bar, or if the tool is to be used as a facing bar, to square a shoulder inside a piece of work as shown in Fig. 129, the cutter B is removed from the bar and after the bar is in place it is inserted and held by set screw C.

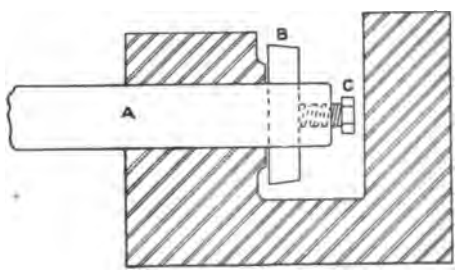


Fig. 129.

For large work, a counterbore may be made as shown in Fig. 130, A being the cutter bar which should be made of tool steel $\frac{1}{16}$ to $\frac{1}{8}$ inch larger than finish size. After taking a roughing chip, leaving it a trifle large, the slot should be made to receive the cutter C. This is done by drilling a series of holes as shown in Fig. 131. After prick punching the bar, it should be clamped to a drill press table, holding the bar in a pair of V blocks. The prick punch marks should be set in a position that will insure the

drill holes going through the center of the bar; this can be done as follows: place the square against one side of the bar, measure to the center, then place the square against the opposite side and measure in the same manner. When the distance is the same on each side from the square blade to the centers, the piece is in the proper position for drilling. The drill press table may then be swung around until the prick punch marks are in proper location

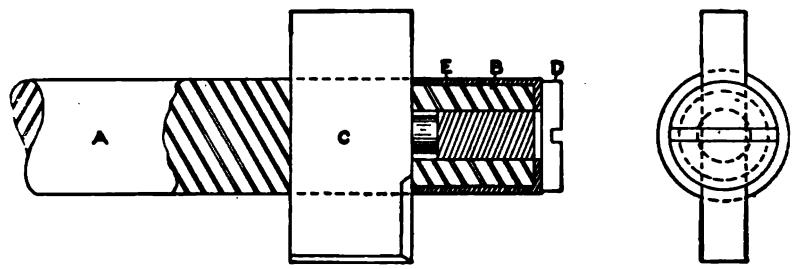


Fig. 130.

with the spindle of the press. After drilling, a drift may be driven through to break the walls separating the holes and the slot filed to size. The bar should be placed with one end in the steady rest and the other end strapped to the head center of the

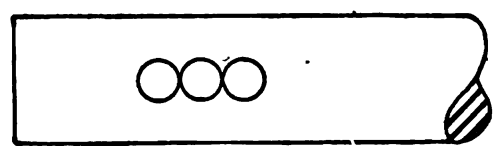
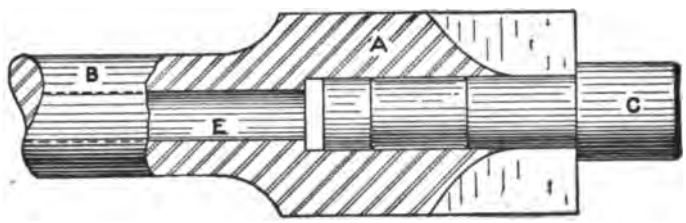


Fig. 131.

lathe. The screw hole in the end is now drilled and tapped into the slot in order that the screw may bind the cutter. The end should be countersunk to provide a center for finish turning. The bar may be turned to size at A and the pilot finished to size. The screw D should have a head $\frac{1}{16}$ inch larger than the part B in order that it may hold the sleeve in place, should it have a tendency to come off when removing the counterbore from the hole. The cutter C should be a close fit in the slot. A headless screw should be made short, so that it will not interfere with the dead center of the lathe when it is screwed to place against the

cutter blank. It is intended to be used when turning the cutter to the right diameter, and should be kept for that purpose.

Counterbores with Inserted Pilots are useful when the counterbores need frequent sharpening, or when a variety of different sized holes are to be counterbored to the same size. A



Fig, 132.

common form of counterbore having an inserted pilot is shown in Fig. 132.

When making this counterbore the stock should have a roughing chip taken off and the hole E drilled part way from the shank end. This drilling may be done in the speed lathe, holding the drill in a chuck in the head spindle; the center in the opposite end of the piece should be on the dead center of the lathe. If the piece is turned one-half revolution occasionally the drill will cut accurately enough, as perfect alignment is not necessary in this hole, since it is intended only for use when driving out the pilot.

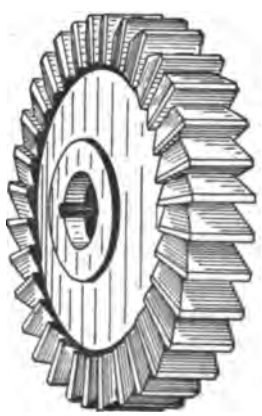


Fig. 133.

After drilling, the shank end should be carefully countersunk. The piece may now be turned to grinding size which should be from .015 to .020 inch all over. After turning the outside, the hole for the pilot may be drilled and bored, running the large end of the counterbore in the steady rest. The counterbore should have four cutting edges for all ordinary work; these may be cut with a side milling cutter with a face sufficiently wide to cover the width of tooth. The form of cutter is shown in Fig. 133, while an end view of the teeth is shown in Fig. 134. When mil-

ling the teeth, the counterbore can best be held in the chuck on the spiral head. If a more stubbed form of tooth is needed than the one shown in Fig. 132, the spiral head may be tipped to the desired angle and the cutter fed through instead of sunk into the counterbore. After milling, the burrs should be removed, the counterbore stamped and hardened. While hardening, it should be heated to a red nearly the whole length of body; when dipped in the bath it should be inverted in order that the teeth may be uppermost, it should then be worked up and down rapidly in the bath until the red has entirely disappeared. It should be allowed to remain in the bath until cold. If larger than 1 inch diameter the *strain* should be removed immediately upon taking from the bath by heating over the fire as already explained. The pilot should be turned as shown in Fig. 135. A and BB should be left

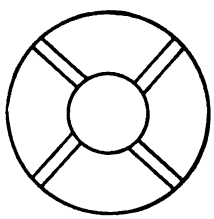


Fig. 134.

Fig. 135.

about .010 inch large for grinding after hardening; C should be turned $\frac{1}{32}$ inch smaller than the hole in the mill, as this does not bear when the pilot is in place. A slight depression should be made between the head and the first bearing point B for the emery wheel to pass over when grinding. When hardening, A is the only part that needs to be hard, but, unless a piece of tube is slipped over the stem B when the pilot is put in the bath it will be almost impossible to harden A the entire length and leave B soft. As A is likely to rough up when used it is best to harden a short distance on the stem B, unless there should be a great difference in size between A and B; in which case a tube, or a piece of iron with a hole drilled in the end the size of B and having the end beveled as shown in Fig. 136, should be slipped over B when the pilot is heated. This cover should be slipped over the stem and up against the shoulder of the head to prevent a *water line*;

if this precaution is taken there is no danger of pilot cracking under the head. After hardening and tempering, the pilot may be ground to size at A, and the portions B B ground to fit the hole of the counterbore. After grinding, the pilot may be forced into place. The counterbore may be ground with the pilot in position. When dull the pilot should be forced out of the counterbore and the cutting edges ground with an emery wheel.

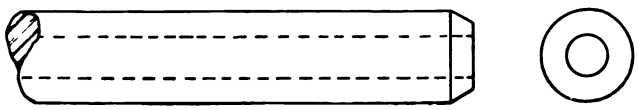


Fig. 136.

Combination Counterbores are made when it is necessary to change the size of counterbore and pilot frequently. A shank or bar is made to accommodate different sizes of cutters, and sleeves serve as pilots. In Fig. 137, A is the cutter, B the pilot which is tapped in the end to receive a screw which holds the sleeves, and C the shank which is held in a chuck or collet, when the counterbore is in use.

After taking a roughing chip off the bar, the end B is run in

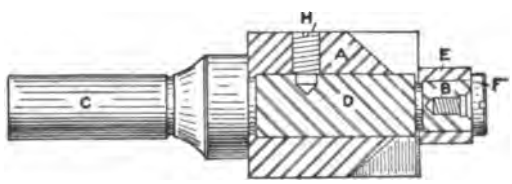


Fig. 137.

the steady rest and the hole for the screw F is drilled and tapped. The outside end is countersunk to a 60° angle to run on a center. When machining the holder, the portions B, C, and D should be left about .010 inch larger than finish size to allow for grinding. But if no grinder is at hand it may be left a few thousandths of an inch above size, and filed to finish dimensions.

The body (or cutter) A, should have a hole $\frac{1}{16}$ inch smaller than finish size drilled through it; the outside surface should be turned off, and the piece annealed. If a grinder having an inter-

nal grinding attachment is at hand, the hole in the cutter should be left .005 inch small for grinding. If such an attachment is not at hand the hole may be reamed to finish size. The outside diameter should be left about .010 large; the ends should be faced to length, and the teeth cut. If four teeth are to be cut, the work may be done with a side milling cutter as shown in Fig. 133. The counterbore should be held in a chuck on the spiral head

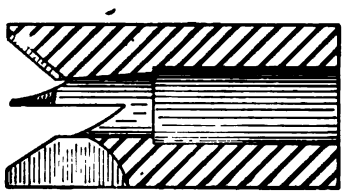


Fig. 138.

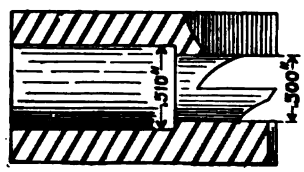


Fig. 140.

spindle, which should be tipped to produce a strong tooth as shown in Fig. 137. Before hardening, the hole should be drilled and tapped for the screw H which holds the counterbore to the bar. To harden, the counterbore should be given an even, low red heat, and plunged in water or brine in such a manner that the bath will come in contact with the teeth. If the teeth are stubbed

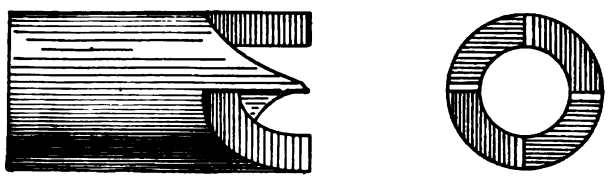


Fig. 139.

and strong the temper need not be drawn more than to a light straw color.

The screw H should be made of tool steel having a projection $\frac{1}{8}$ inch long on one end, turned to the bottom of the thread; this is to enter a hole drilled in the bar or holder, and keep the counterbore from turning. The end of the screw should be about .005 inch smaller than the hole. The screw should be hardened and drawn to a blue color. The sleeve intended to go on the pilot E should be made of tool steel, hardened and ground to size inside and out. The screw F may be made of machinery steel,

and case-hardened sufficiently deep by heating to a red and sprinkling with powdered cyanide of potassium, after which it is reheated and plunged in water.

HOLLOW MILLS.

Hollow mills are used in screw machines and turret lathes for roughing down and finishing. They are also used in drill press work in finishing a projection which must be in some given position; when thus used they are generally guided by a bushing in a fixture, to bring the projection in the proper location.

For roughing out work on a screw machine or turret lathe, solid mills having strong stubbed teeth are preferred for rigidity. For finishing they are made adjustable in order to get *exact* sizes. Fig. 138 shows a solid hollow mill having the cutting end hol-

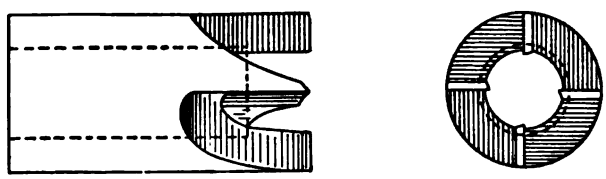


Fig. 141.

lowed out in the form of a V, in order that it may center itself when starting to cut. Fig. 139 shows a form of solid hollow mill intended for use in squaring up a shoulder at the end of a cut that has been made with a mill of the form shown in Fig. 138, or it may be used for roughing out a piece; however, it will not center itself as readily as the one shown in Fig. 138.

For small hollow mills some tool makers advocate three cutting teeth, while others claim better results with four teeth on all sizes.

The rear of the mill is bored somewhat larger than the cutting end, to allow it to clear on long cuts. The cutting end must be relieved or it will bind and rough the work, and probably twist it off in the mill. There are several methods of relieving mills; the more common one is to ream the hole tapering, making it larger at the back end, as shown in Fig. 140. Another method is to file back of the edges, as shown in Fig. 141.

For making hollow mills having the same outside diameter, it is advisable to use a holder of the form shown in Fig. 142,

having a taper shank which fits the spindle of a lathe. The hole in the other end of the holder should be the size of the holder in the screw machine or turret lathe, which holds the mills when in use. The steel for the hollow mills should be cut to length and turned to the proper diameter to fit the holder. After putting the blank in the holder, the ends may be squared and the holes drilled and bored to the desired sizes. If the mill is to be of the form shown in Figs. 138, 139 and 140, the cutting end may be reamed with a taper reamer to give the necessary clearance. The reamer should be run in from the back end in order that this end of the hole be larger. For the form shown in Fig. 141, the hole at the cutting end should be straight and to finish size.

The mill is now ready for cutting the teeth. If four cutting edges are to be given, a side milling cutter may be used of a

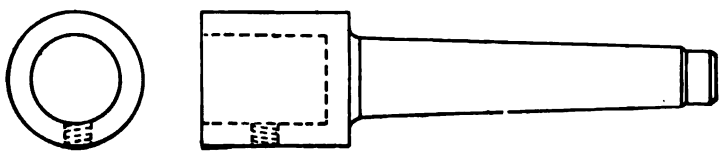


Fig. 142.

diameter about double the diameter of the hollow mill to be cut. The blank should be held in a chuck on the end of the spindle in the spiral head. For a strong tooth, the spiral head may be set at an angle that will produce a tooth as shown in Fig. 143, by feeding the milling cutter *through* the blank. If a deeper tooth is desired, the spiral head may be set so that the blank will be in a vertical position, and the milling cutter fed in until the desired form and depth of tooth is obtained.

An Adjustable Hollow Mill may be made by following the instructions given for *solid* hollow mills, except that the mill must be split as shown in Fig. 144, in order that the size of hole in the mill may be altered. There are two methods of adjusting the mill: the outside of the cutting end of the mill is tapered, and a collar having a corresponding taper hole is forced on the mill. The collar closes it, and causes it to cut smaller. The other method is to turn the outside of the hollow mill straight, and close by means of the clamp collar shown in Fig. 145. As adjust-

able hollow mills are generally used for finishing cuts, and are not used when taking heavy cuts, the teeth may be made finer than those of solid mills used for roughing. The teeth being nearer together will finish a cylindrical piece more accurately than if the teeth were cut farther apart. It is customary to give adjustable hollow mills to be used for finishing from six to eight teeth. The cutting edges should be cut radial for most work. Better results

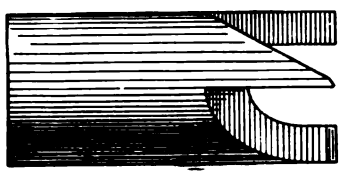


Fig. 143.

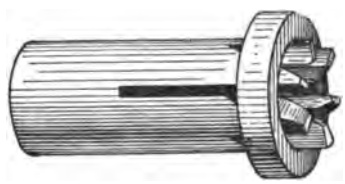


Fig. 144.

will be obtained if the hole in the cutting end of the mill is left .005 inch small, and ground to size after the mill is hardened.

The hollow mill, whether it be solid or adjustable, should be hardened a trifle farther up than the length of the teeth, and drawn to a straw color. The mill is sharpened by grinding on the ends of the teeth.

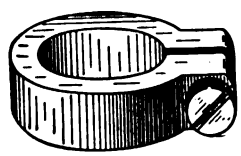


Fig. 145.

Hollow Mill with Inserted Blades. For large work, hollow mills are made having inserted blades. The hollow mill with removable blades, shown in Fig. 146, does good service on rough work; the blades may be made of self hardening steel and inserted in a machine steel body. The grooves in the body to receive the blades should be milled with a cutter whose thickness corresponds to the size of the steel to be used for the blades. The grooves are cut somewhat deeper at the front end of the holder in order that the blades may have clearance to prevent binding. The edge of the slot corresponding to the cutting edge of the blade should be radial.

Two collars should be made of machinery steel having holes sufficiently large to allow their being placed on the mill when the blades are in the slots. Each collar should be provided with the same number of set screws as there are blades in the mill. One collar holds the blades in the holder, while the other is placed nearly at the ends of the blades to support them while cutting. This

form of mill is used on cuts not exceeding one inch in length, as the blades must project beyond the holder to the desired length of the cut.

The size of cut may be changed somewhat by setting the cutters back or ahead in the slots, or paper may be placed in the slots under the blades to increase the diameter of the cut. The blades are set to an even length by bringing them against a surface perpendicular to the axis of the body of the tool.

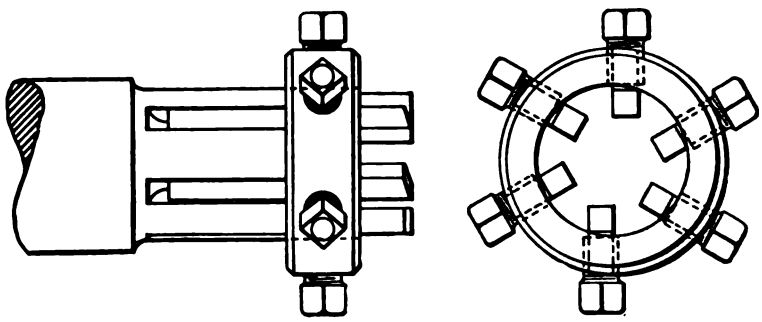


Fig. 146.

Hollow Mill with Pilot. It is often desirable to mill the outside of a projection central with a hole passing through it. This may be done very satisfactorily with a hollow mill having a pilot as shown in Fig. 147. It is advisable to hold the pilot in place by means of a set screw. In order to give clearance to the teeth to

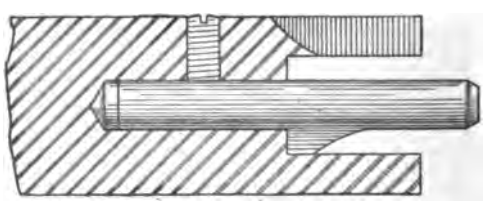


Fig. 147.

prevent the mill binding when cutting, the hole may be bored tapering. 010 inch in $\frac{1}{2}$ inch of length, making it largest at the back end.

When hardening a mill of this description it is advisable to dip it in the bath with the cutting end *uppermost* working it up and down rapidly. After hardening, it may be drawn to a straw color. The pilot should be turned .010 inch above finish size, hardened, and drawn to a brown color, and ground to the desired dimensions.

FORMING TOOLS.

Forming tools are used when several pieces are to be made of exactly the same shape. They are particularly valuable for giving the desired shape to formed mills and similar tools and are extensively used in duplicating a given shape on work produced in the screw machine.

Forming tools are made flat and circular in shape. When used in the lathe for shaping milling machine cutters and similar tools they are generally made flat; for backing off formed milling machine cutters they are always made flat; for screw machines in duplicating a given shape they are made both flat and circular.

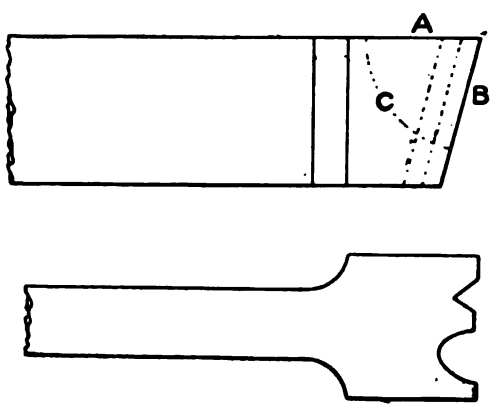


Fig. 148.

The flat forming tool is made as a solid cutter, the tool and shank being in one piece as shown in Fig. 148, or the cutter and shank may be made separate as shown in Fig. 149. When but one forming tool is to be made, that shown in Fig. 148 will be found to be inexpensive; but for making many tools, it will be found much cheaper to adopt the plan shown in Fig. 149.

On certain classes of work it is advisable to use a forming tool on a holder of the description shown in Fig. 150, which is known as a spring holder. On account of its design it may spring somewhat when used on heavy cuts, thus reducing the tendency to chatter. It is necessary to make these holders of tool steel, giving them a spring temper at point marked A. The slot

B allows the forming blade D to spring away from the work when under heavy strain. The blades may be planed up in long strips and cut off the required length. The tongue E should fit

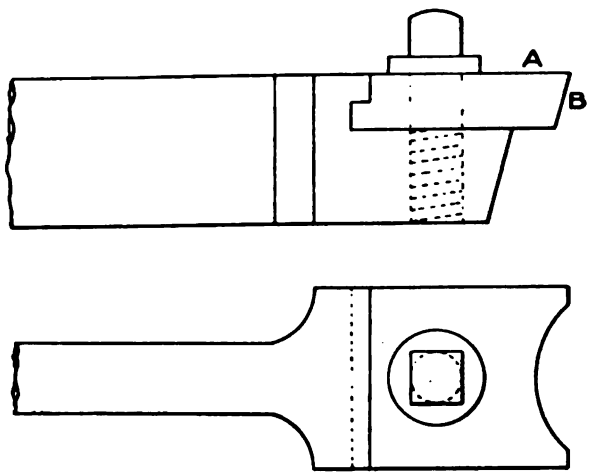


Fig. 149.

the slot O, which, with two cap screws through F and G, securely holds the blade in position.

In order that a forming tool may cut readily, it is necessary to give the surface marked B a sufficient amount of clearance.

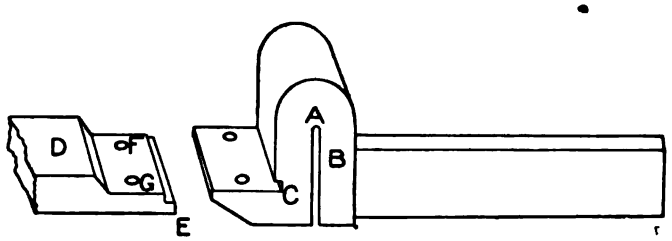


Fig. 150.

For tools to be used for shaping milling machine cutters and similar tools, a clearance of 10° to 15° will be ample; that is, the angle should be from 80° to 75°. But if the tool is to be used for backing off the teeth of formed milling machine cutters, it is necessary to give a clearance of 18° to 22°. When making a

forming tool having the required angle at D, the shape can be produced by tipping the blank to the required angle and planing or milling with a tool having exactly the shape it is desired to produce. The tool used may be made of a shape enough different from that desired that it may produce the proper shape when the cutter is in a vertical position, and the blank at a given angle from that position as shown in Fig. 151. Or, the tool may be held in the tool post (or in a fixture made for the purpose) of the shaper or planer at the same angle as the blank being cut, as shown in Fig. 152, and it will produce a shape corresponding very closely with its own.

Fig. 151.

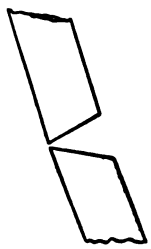


Fig. 152.

For screw machine and similar work for duplicating given shapes, a forming tool is made of the shape shown in Fig. 153. A represents a holder used by the Brown & Sharpe Mfg. Co. for use on their screw machines. B shows the forming tool blank. The desired shape is cut in the surface marked C.

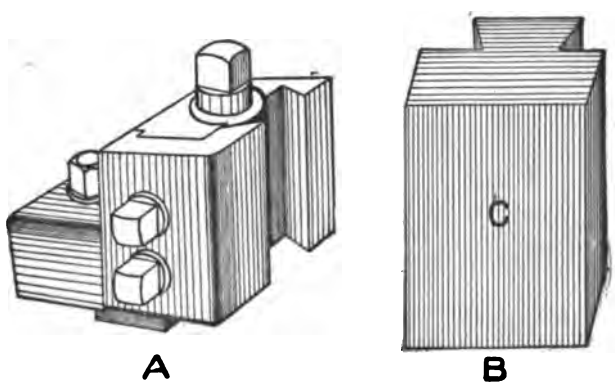


Fig. 153.

Circular Forming Tools are used very extensively on screw-machine and similar work. They are valuable on account of the ease with which any number of them may be produced, provided a forming tool is used in producing the shape on the face as

shown in Fig. 154. After the blank has been formed to the desired shape, it may be milled as shown in Fig. 155 in order to provide a cutting edge. If it is desired to produce a shape on the piece being machined to correspond with the shape of tool, it is necessary to have the cutting edge radial as shown in Fig. 155. In order to feed the tool into the stock faster than can be done with the form shown in Fig. 155, it is given more clearance as shown in Fig 156. On a tool whose cutting edge is not radial and will not produce a shape corresponding to its own, it is necessary when cutting the edge with the rake shown in Fig. 156, to make the face of the tool slightly different in form from that desired.

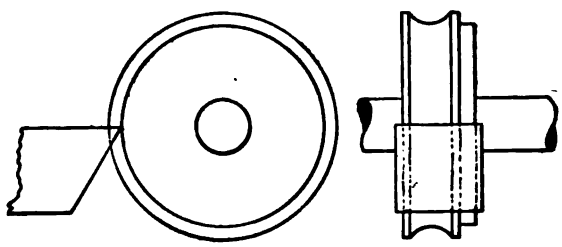


Fig. 154.

After milling the cutting edge, the name or number of the tool may be stamped on it, after which it is ready for hardening. When extremely high carbon steel is used, the tools sometimes crack while hardening from the strain incident to their shape. In order to overcome this tendency, some tool makers make two extra cuts in the edge as shown in Fig. 157, in order that the hardened edges may not be cracked from the contraction. Two cutting edges, as shown in Fig. 158 are often given tools in order that it may not need to be ground as often as when it has but one cutting edge. It is not necessary to stop the screw machine nearly as long to grind both cutting edges, as to stop the machine twice to grind the same edge on account of the time necessary to rig up the grinder.

When hardening, the tool should be heated to a low red and plunged in a bath of water or brine from which the chill has been removed; it should be worked around well in the bath. If

the temper is not to be drawn after hardening, the tool may be held over the fire after removing from the bath and heated sufficiently to remove the tendency to crack from internal strains.

On account of some weak projection, which, because of its

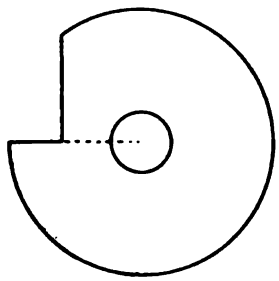


Fig. 155.

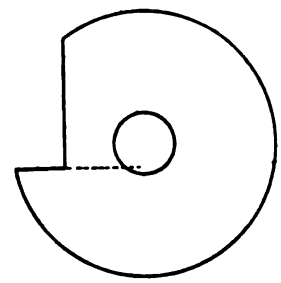


Fig. 156.

shape is likely to break when used, it is sometimes necessary to draw the temper. It is not always necessary to draw the temper to a straw color, and as a light straw is the first temper color visible, some other means must be employed. The tool may be placed in a kettle of oil, and by means of a thermometer any

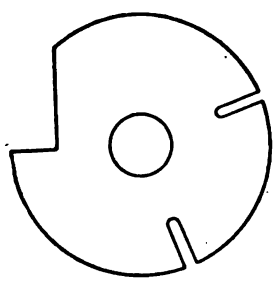


Fig. 157.

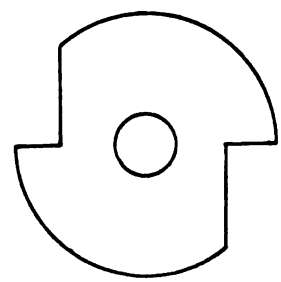


Fig. 158.

degree of heat may be obtained. The writer recalls a certain forming tool which was too brittle when left as it came from the hardening bath, yet was not hard enough when drawn to even the faintest straw color. When taken from the hardening bath, it was placed in a kettle of boiling water and left there about five minutes. The heat of the water at 212° reduced the brittleness

so that the tool stood up in a good shape, yet it did not perceptibly soften it.

The following is an excellent plan: Use a bath of water having about one inch of oil on top; the tool after being heated red hot is plunged down through the oil into the water. Enough oil adheres to prevent the sudden shock which the steel received when plunged into the cold bath.

"Pack Hardening" also gives excellent results.

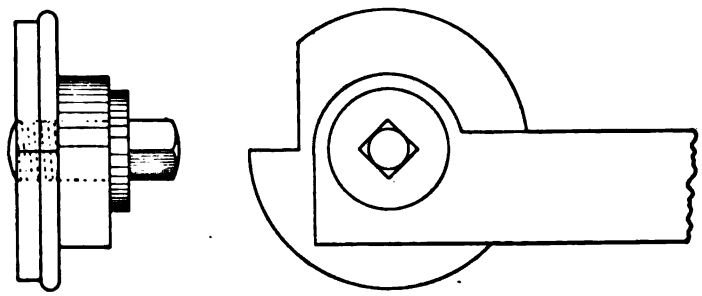


Fig. 159.

Tool Holders. The form of the holder for the tool depends on the class of work to be done and the machine in which it is to be used. Fig. 159 shows a design commonly used for hand screw machine work. If the cuts are comparatively light, the side of the tool and holder may be flat as shown. If, however, heavy cuts are taken which would have a tendency to turn the tool, it is often made with a taper projection on one side as shown in Fig. 160, the holder having a corresponding taper hole to receive the projection. This projection should be a good fit in the taper hole, but should not go in far enough to strike the bottom, neither should the side of the tool bear against the side of the holder.

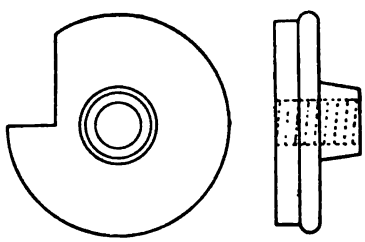


Fig. 160.

When used in automatic screw machines the holder is generally of a different shape from that used for hand screw machines.

A very common form is shown in Fig. 161. This holder is made in the form of an angle iron. The fixture (holder) is fastened to the tool rest by means of the bolt shown. The tool is fastened to the upright side of the holder by means of the bolt represented with its head let into the forming tool.

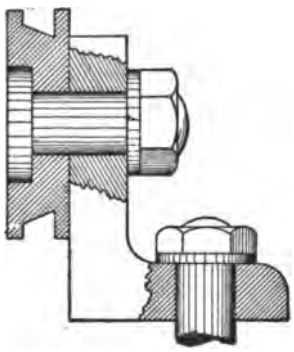


Fig. 161.

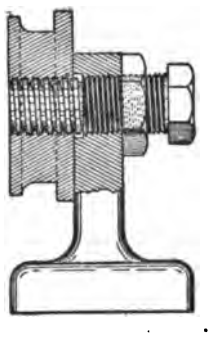


Fig. 162.

When extra heavy cuts are to be taken with a forming tool, it is sometimes considered advisable to make a holder of the form shown in Fig. 162. The holder is bolted to the tool rest in the same manner as the one represented in Fig. 161. A square thread having a pitch of five or six threads to the inch is cut in the forming tool; the thread should be right or left hand depending on which side of the machine the tool is to be located when in use, the thread being such that the tool will tighten by the pressure exerted by the cut. To get an adjustment, the thread in the holder must be of a finer pitch than that in the forming tool and of the same hand. If desired, this tool may be used in the ordinary form of holder shown in Fig. 161 by use of the bolt shown in Fig. 163.

Fig. 163.

MILLING CUTTERS.

Milling machine cutters are made in two different forms: solid and with inserted teeth. It is customary in most shops to

make cutters up to 6 or 8 inches in diameter solid, and above this size they are made with inserted teeth.

SOLID CUTTERS.

When making solid cutters it is advisable to use steel somewhat larger than the finish diameter of the cutter. A hole should be drilled in the blank $\frac{1}{16}$ inch smaller than the finish size of hole and the outside surface should be turned off. After annealing, it should be put in the chuck on the lathe, the hole bored and reamed to size and the hole recessed as shown at C in the sectional view of Fig. 164.

The piece should now be placed on the mandrel, and turned to the proper diameter and length. The teeth should be cut in the universal milling machine, or in a milling machine provided with a pair of index centers. The number of cutting edges for solid milling cutters varies somewhat according to the nature of the work to be done, but for general shop use the following table will be found satisfactory.

CUTTING EDGES FOR MILLING CUTTERS.

Diameter of Cutter.	No. of Cutting Edges.	Diameter of Cutter.	No. of Cutting Edges.
¼	6	2¼	20
½	8	3	24
1	10 or 12	3½	26
1¼	14	4	28
1½	16	5	30
2	18	6	32

For most work it is desirable to have the faces of the teeth radial as shown in Fig. 164. However, when milling cutters are made to run in the direction of the feed or onto the work instead of against it, the teeth should be given a negative rake (cut ahead of the center) as shown in Fig. 165, as it has a tendency to keep the piece being milled from drawing toward the cutters.

When cutting the teeth, it is necessary to use a cutter that gives sufficient depth of tooth to provide a receptacle for chips, and also gives a form that supports the cutting edges. A cutter may be used that will produce an angle of about 50° between the

face and back of the tooth as shown at A in Fig. 164. The cutter should cut deep enough to leave the lands about $\frac{1}{32}$ inch in width at the cutting edges.

The form of cutter shown in Fig. 164 is known as a Side

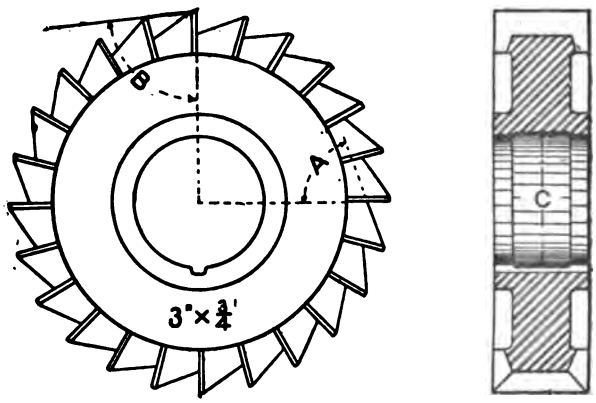


Fig. 164.

Milling Cutter. When cutting the teeth on the sides, it is necessary to put the cutter on a plug whose upper end does not project much above the top face of the cutter; this plug may be made straight and held in the chuck on the end of spindle in the spiral head. Such a plug is shown in Fig. 166 inserted in the cutter. If *many* cutters are made with teeth on the sides, it is advisable to make an expanding arbor, Fig. 167, whose shank fits the taper hole in the spindle of the spiral head. When milling the teeth on the sides, the index head must be inclined a little so that the side of the mill will stand at a small angle from the horizontal in order that the lands of the teeth may be of equal width at each end. The amount of this inclination cannot readily be computed.

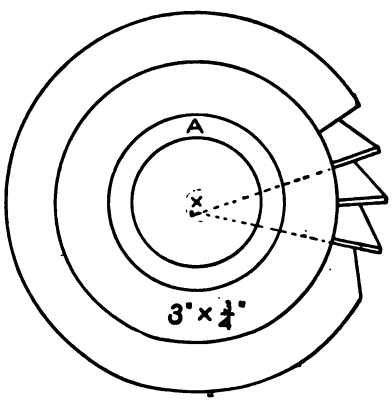


Fig. 165.

It is formed by first cutting a tooth leaving the cut somewhat shallow, then turning to the next tooth. After cutting the second tooth, the change in inclination will be apparent.

When the teeth are cut and the burrs removed, the diameter and length of the cutters may be stamped as shown in Fig. 164. The cutter is now ready for hardening. To successfully harden, it is necessary to have a *low, uniform* red heat; the teeth must be no hotter than the portion between the hole and the bottom of the teeth. When held toward the light there should be no trace of black in the interior of the cutter. When a uniform heat no higher than is necessary to harden the steel has been obtained, the cutter may be plunged into brine from which the chill has been removed; it should be worked around rapidly in the bath until the singing has ceased. It should then be removed from the brine and immediately plunged into oil and allowed to remain there until cold. When cold, the cutter may be taken from the oil and heated sufficiently to prevent cracking from internal strains. The cutter may now be brightened and the temper drawn to a straw color.

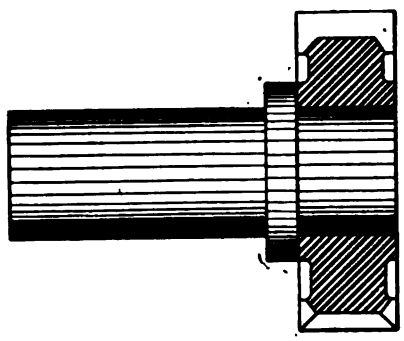


Fig. 166.

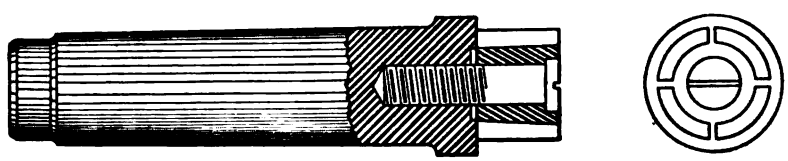


Fig. 167.

Grinding the Hole to Size. It is customary to ream the holes in milling cutters to size, and if the cutter contracts in hardening, the holes are brought to size again by lapping with a lead or cast iron lap, by means of oil and emery. However, this operation does not provide for the enlarging of the hole. While this

is an unusual occurrence, it *sometimes* happens, and as a consequence the cutter does not fit the milling machine arbor and cannot do as good or as much work as it should.

On account of the necessity of having a correct fit on the milling machine arbor, it is advisable to ream the hole of the cutter with a reamer about .005 inch under the size of the arbor and finish by grinding after the cutter is hardened.

When grinding the hole to size, the cutter may be held in a chuck and ground with a small emery wheel, using the internal grinding attachment as shown in Fig. 168. This attachment is

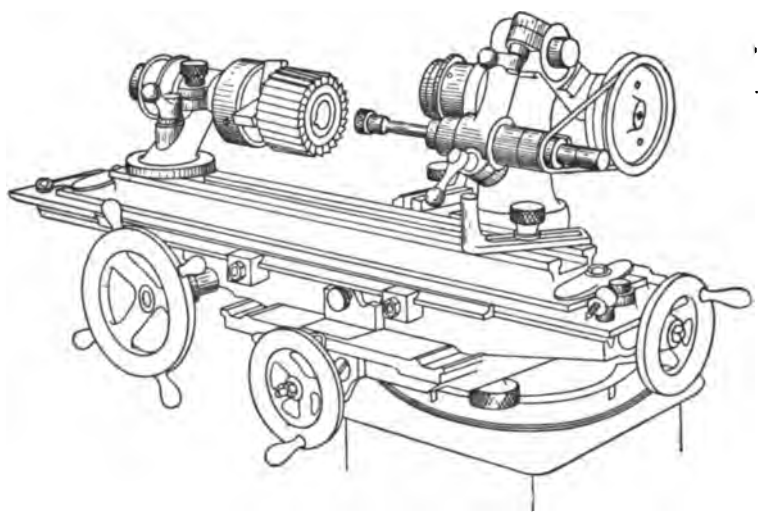


Fig. 168.

so designed that it may be swung out of the way when gauging the size of the hole as shown in Fig. 169. After grinding the hole to size it is advisable to grind the shoulders on each side of the cutter straight and true with the hole in order to prevent any possibility of springing the milling machine arbor by any untruth on the part of the cutter, and to prevent any possibility of the cutter running out of true. The shoulder (or boss) referred to is shown in A, Fig. 164.

There are two methods of grinding the shoulders. By one method the outer shoulder and the hole are ground at the same

setting; if this is done properly this shoulder will be true with the hole. The chuck is now removed from the grinder and a face plate having an expanding plug is put in its place. The shoulder that has been ground is placed against the face plate with the expanding plug in the hole of the cutter. The outer shoulder may be ground after the plug is expanded until the cutter is held rigidly in place against the face plate which should run perfectly true.

By the other method both shoulders are ground while on an

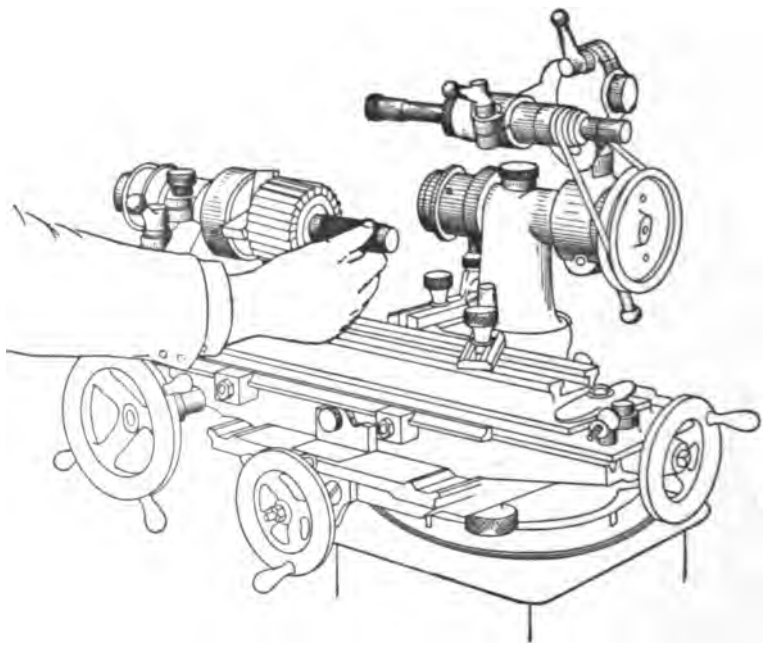
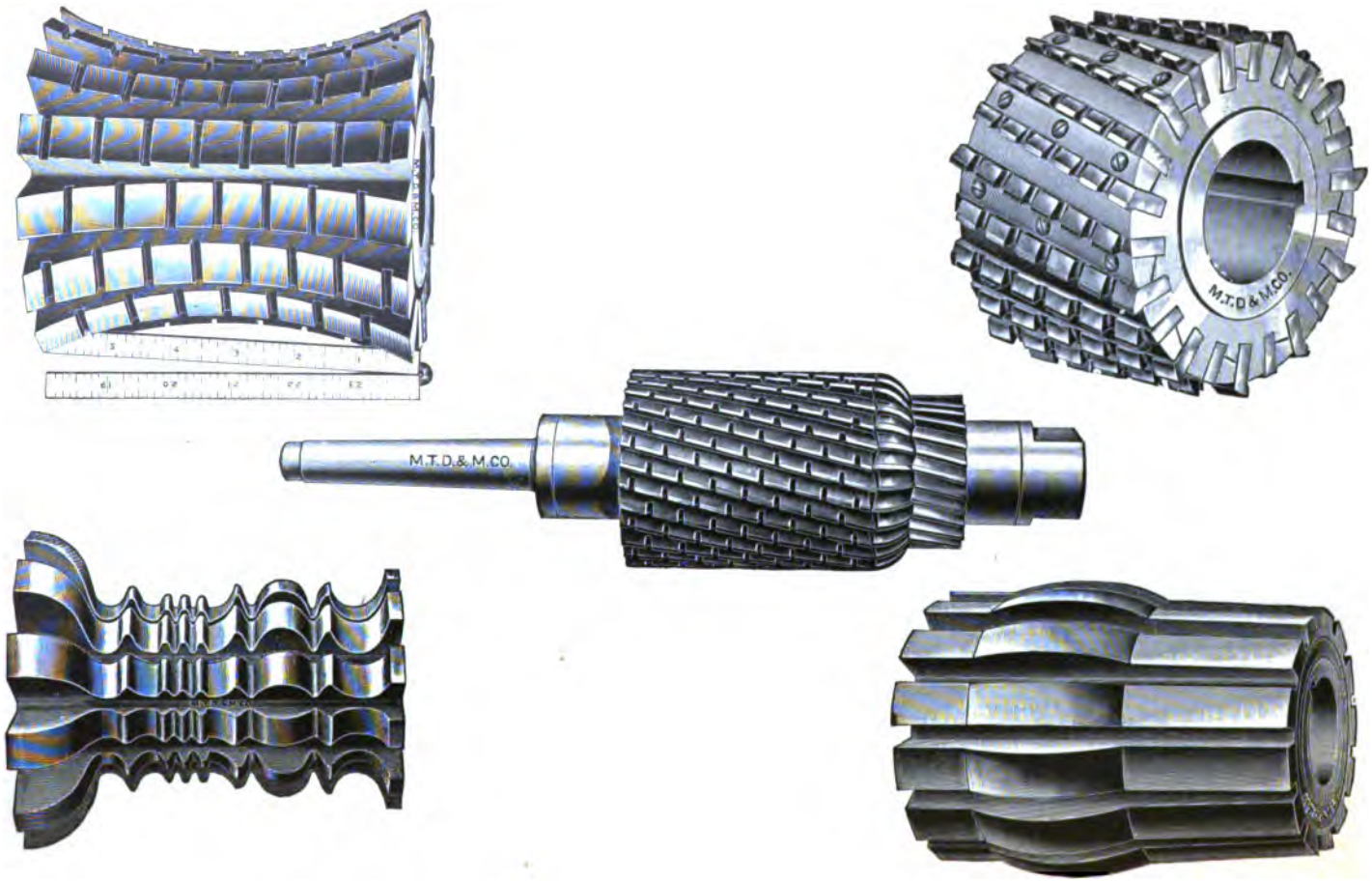


Fig. 169.

arbor which is necked down each side of the cutter as shown in Fig. 170. This necking allows the wheel to traverse the whole length of the shoulder and not into the arbor, as would be the case if an ordinary mandrel were used.

Grinding. In order to get the best results from a milling cutter it is necessary to use some form of grinder having a means of properly locating each tooth as it is presented to the wheel. This is usually accomplished by a finger which may be adjusted



Representative Types of Milling Cutters Manufactured by the Morse Twist Drill and Machine Company.

to the proper height to produce the required amount of clearance. The teeth may be given a clearance of about 3° as shown at B, Fig. 164. With this amount of clearance the cutter works freely and retains its edge; if more clearance is given the cutter is

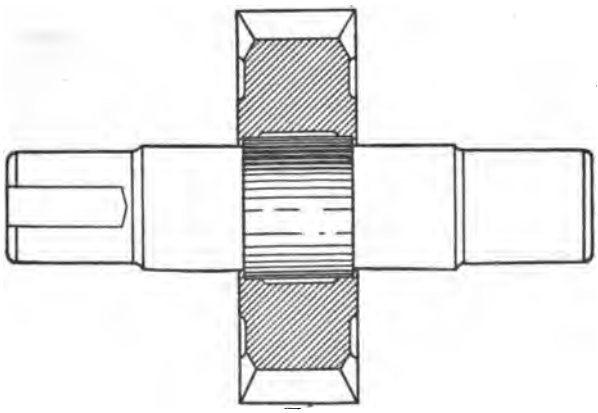


Fig. 170.

likely to chatter, and the edges of the teeth will become dull rapidly.

Fig. 171 shows a cutter in position for grinding the teeth; it will readily be seen that the tooth being ground rests on the finger or tooth rest; this finger may be adjusted to give any desired amount of clearance to the tooth. For grinding the teeth on the *side* of a milling cutter, a small emery wheel may be used in order to get the necessary amount of clearance without touching the tooth next to the one being ground.

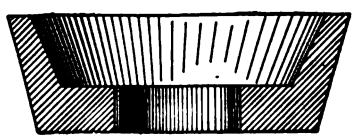


Fig. 172.

If a grinder is used which will take a cup wheel as shown in Fig. 172, and whose table can be turned to bring the cutter in the position shown in Fig. 173, a form of clearance is given the tooth which is more satisfactory than if ground with a small wheel. With the cup wheel the line of clearance is straight, while with the small plain wheel it is hollowed out, and as a consequence the cutting edge is weak.

Spiral Milling Cutters. It is customary in most machine

shops to make all milling cutters of more than ½ inch face with teeth cut spirally as in Fig. 174. The amount of spiral given the teeth varies in different shops and on different classes of work.

The object of providing spiral teeth is to maintain a uniformity of cutting duty at each instant of time. With teeth parallel to the cutter axis, the tooth on meeting the work will take the cut its entire length at the same instant, causing a jump to the

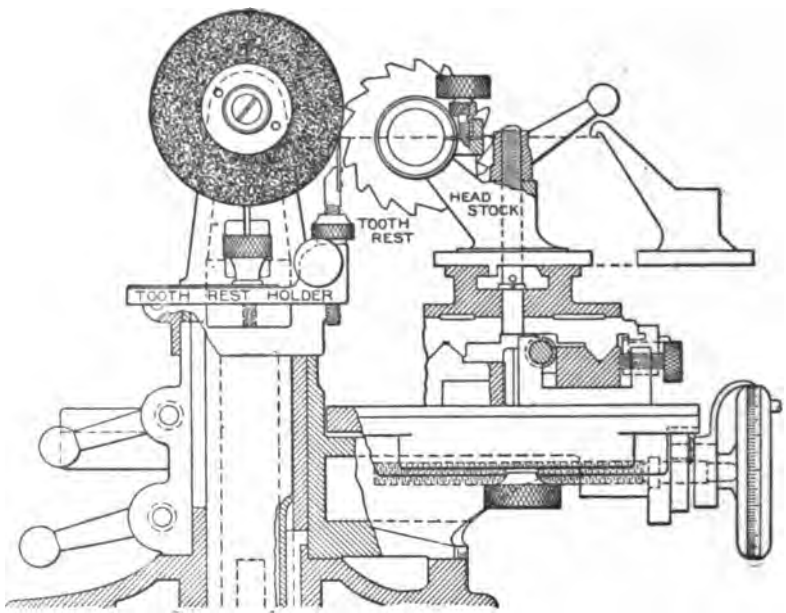


Fig. 171.

work on account of the springing of the device holding the work, and of the cutter arbor. If the teeth are cut spirally, the cut proceeds gradually along the whole length of the tooth, and after the cut is started a uniform cutting action is maintained, producing smoother work and a truer surface, especially in the case of wide cuts.

Milling cutters may be cut with either a right or left hand spiral, or helix, although it is generally considered good practice to cut a mill having a wide face with a spiral that will tend to force the cutter arbor into the spindle rather than to draw it out; then again, it is better to have the cutting action force the solid

shoulder against the box, rather than to draw the adjusting nut against the box.

Where two very long mills are used on the same arbor and it is found necessary to cut them with a quick spiral, one cutter is sometimes cut with a right hand spiral and the other with a left hand spiral, in order to equalize the strain and reduce the friction resulting from the shoulder of the spindle pressing so hard against the box.

Special care should be taken in cutting spiral milling cutters

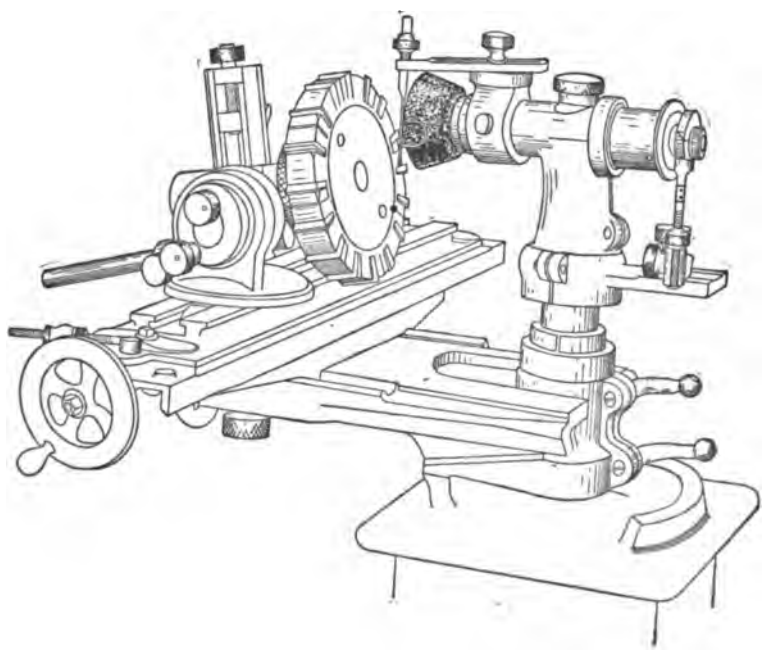


Fig. 173.

that the work does not slip. When a cut has been taken across the face of a cutter it is best to lower the knee of the milling machine, thus dropping the work away from the mill while coming back for another cut; the knee can then be raised to its proper position which may be determined by means of the graduated collar on the elevating shaft of the machine.

As it is important that the face of the cutting tooth be radial and straight, it will be found necessary to use an angular cutter

of the form shown in Fig. 175, as cutters of this form readily clear the radial face of the cut and so remain sharp longer and produce a smoother surface to the face of the tooth than if cut with an angular cutter of the form used for cutting teeth which are parallel to the cutter axis.

The angular cutters for spiral mills are made with either 40°, 48° or 53° on one side and 12° on the other.

By setting the cutter, as shown in Fig. 175, so that the dis-

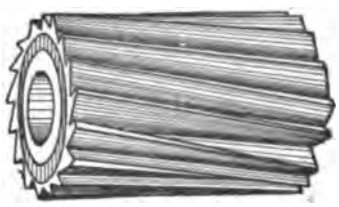


Fig. 174.

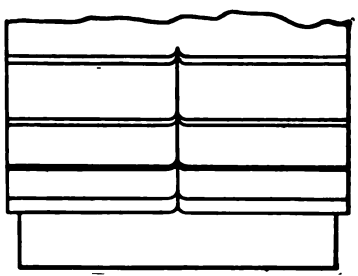


Fig. 176.

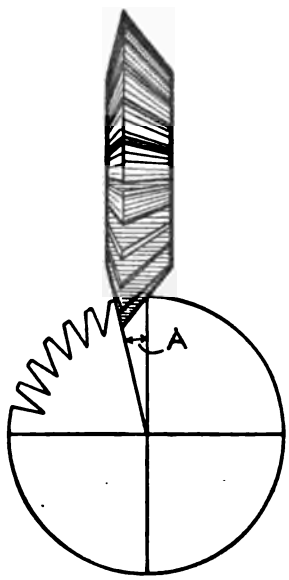


Fig. 175.

tance A is one twelfth the diameter, the face cut by the 12° side of the angular cutter will be nearly radial for the usual proportions.

The setting for cutting the teeth of a spiral cutter must be made before turning the spiral bed to the angle of the spiral.

Milling Cutters with Interlocking Teeth. When two milling cutters of an equal diameter are to be used on the same arbor in such a manner that the end of one cutter is against the end of the other, the corners of the cutting teeth are likely to break away leaving a projection — or fin — on the work as shown

in Fig. 176. In order to overcome this, part of the teeth are cut away on the sides of the cutters; that is, a tooth will be cut away on one cutter and the corresponding tooth on the other cutter will be left full length to set into the recess formed by the cutting away of the tooth. In some shops it is customary to cut away every other tooth while in others two, three or four teeth, will be cut away and an equal number left. Fig. 177 represents a pair of mills having every other tooth cut away, while Fig. 178 represents a pair having four teeth cut away.

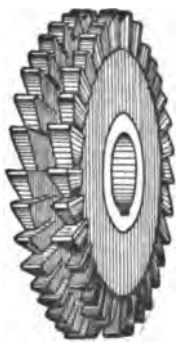


Fig. 177.

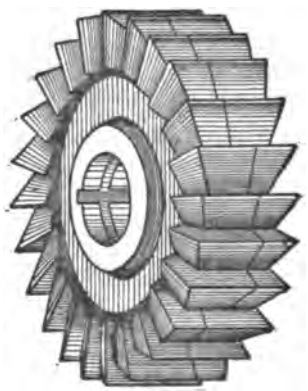


Fig. 178.

In order to cut away the teeth to make the cutter of a form having interlocking teeth, the cutter should be placed on a plug or expanding arbor as described for milling teeth on sides of side milling cutters. By means of a milling cutter having the proper width, the teeth may be milled away, although in case a cutter having several teeth cut away as shown in Fig. 178, it is well to use a narrow cutter and after taking one cut turn the index head so that the next tooth is in position. Continue doing this until the desired number of teeth are cut away. The index head may now be turned to pass over the required number of teeth and the operation repeated.

It is necessary when making cutters with interlocking teeth (sometimes called dodged-teeth) that the milling be deep enough to prevent the corresponding tooth on the other part of the cutter

from striking the bottom of the recess. The parts of the cutter should bear against each other on the shoulders, or hubs.

An excellent form of milling cutter to be used for milling slots or similar work may be made as shown in Fig. 179. This form is less expensive to make than one having interlocking teeth and answers the purpose as well. It is necessary to make an eccentric mandrel of the design shown in Fig. 180 having the eccentric centers on opposite sides of the regular

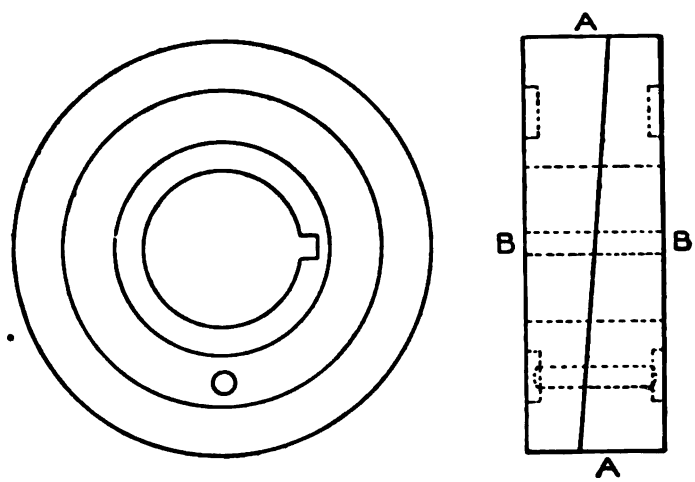


Fig. 179.

centers as shown. The two pieces which make the cutter should be cut from the bar long enough to finish the thickness of the heaviest part A A, Fig. 179. The hole is made $\frac{1}{16}$ inch smaller than finish size, the outside surface turned off and the pieces annealed.

After annealing, the hole may be made the desired size for grinding. One of the pieces may then be placed on the eccentric mandrel, forcing it on until the side that is to be beveled is exactly in the center of the mandrel. The side B may be machined with the mandrel running on the regular centers while the beveled side must be machined with mandrel running on the eccentric centers. When the arbor is running on these centers, a distance half way between the two ends runs true; it is at this point

that the side of the blank to receive the bevel should be located as shown in Fig. 181 provided the eccentric centers are of an equal depth. After machining the two parts of the cutter to shape, they should be so placed on a stud that the two beveled sides will be next each other as shown in Fig. 179, and the thinnest part of one next to the thickest part of the other. The pin hole may now be drilled and reamed for a $\frac{3}{16}$ inch pin which should be inserted. The blank is next placed in the vise on the shaper or planer and the spline slot cut as shown. It is now ready

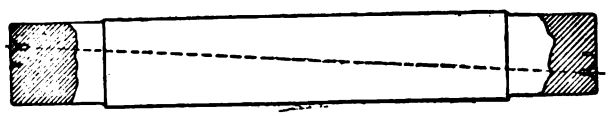


Fig. 180.

to be milled. After the cutter is hardened, the beveled sides may be ground true, the halves put together, hole ground to size, and the cutter ground to thickness, after which the teeth may be ground for clearance. If it is found necessary to increase the width of

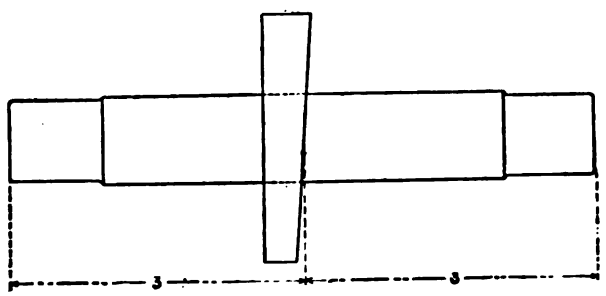


Fig. 181.

the slot, it may be done by shimming between the two parts of the cutter with paper or thin sheet metal; the design of the cutter allows this to be done without leaving any *fin* in the slot.

Nicked Teeth. Spiral cutters with nicked teeth, Fig. 182, are especially adapted for heavy milling. As the chip is broken up a much heavier cut can be taken than would be possible were

an ordinary cutter used. The nicking may be done as follows: An engine lathe may be geared to cut a thread of the required pitch — two threads to the inch will be found satisfactory — and with a round nose tool $\frac{1}{8}$ inch wide cut a thread of sufficient depth that it may not grind out before the teeth will become too shallow to allow further grinding. This thread should be cut before milling the spaces to form the teeth.

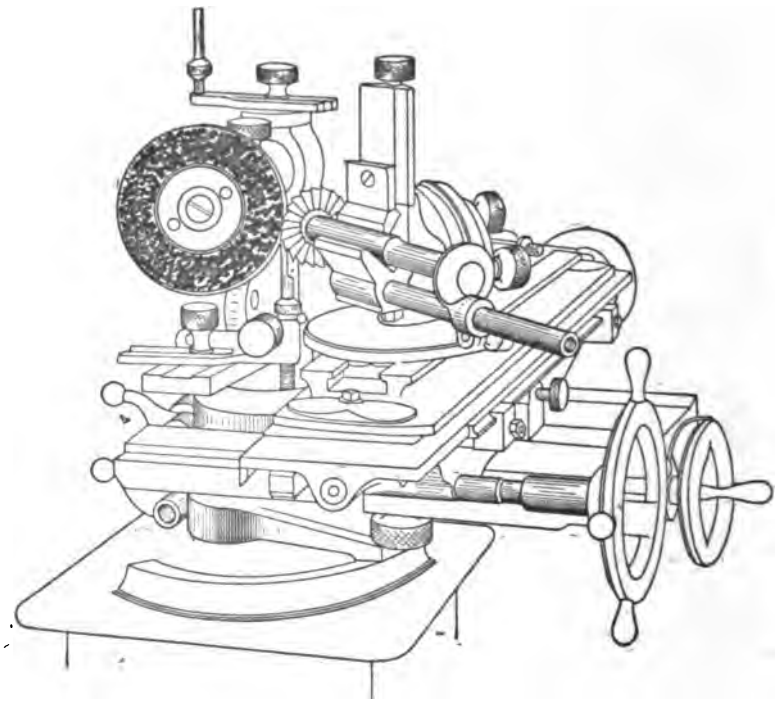


Fig. 183.

Angular Cutters. When making angular cutters the same general instructions given for making solid straight cutters should be followed except that the desired angle should be given.

When milling the spaces which form the teeth, the index head is set at an angle that will cut the edge of the tooth of an equal width its entire length. After removing the burrs the cutter may be hardened and tempered. The hole should be ground

to size and the sides ground true with the hole. It should then be placed on a mandrel or stud and the teeth ground for clearance. Fig. 183 shows the method used in grinding the teeth of a mill of this form.

MILLING CUTTERS WITH INSERTED TEETH.

When milling cutters exceed 6 or 8 inches in diameter, it is generally cheaper to make the body of cast iron or machinery steel and insert in the periphery teeth made of tool steel. There is a variety of methods for holding the teeth in place. If the cutter is narrow, or is to be used as a side milling cutter, the grooves to receive the teeth may be cut straight (parallel to the cutter axis) as shown in Fig. 184. If the cutter face is over one inch long, the slots to receive the teeth should be cut in such a manner that spiral teeth may be used.

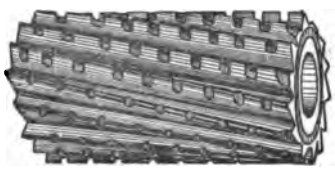


Fig. 182.

While it is a comparatively easy matter to cut the slots

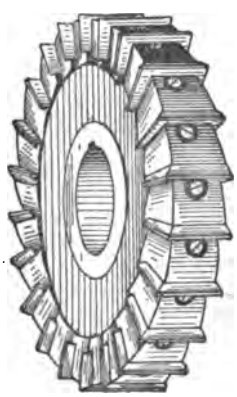


Fig. 184.

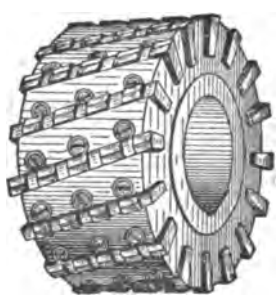


Fig. 185.

spirally, it is difficult to make the teeth of a shape that will fit the spiral slots without the aid of special tools. Consequently the slots are generally milled at an angle to the cutter axis, having the side of slot that corresponds to the face of the tooth equidistant from a radial line at each end of the cut. The face of the

slot at one end would be ahead of the center, while at the opposite end it would be behind the center; this is termed a front rake, and a negative rake respectively.

The slots should be cut somewhat wider than would be necessary were the teeth to be made of a spiral form. After turning to size, the faces of the teeth may be milled spirally to make them radial.

If the mills are intended for heavy work, the teeth may be nicked as already described. The coarse pitch thread should be cut before the teeth are milled spirally.

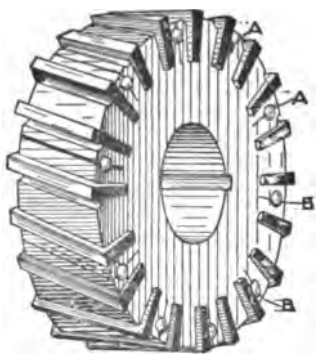


Fig. 186.

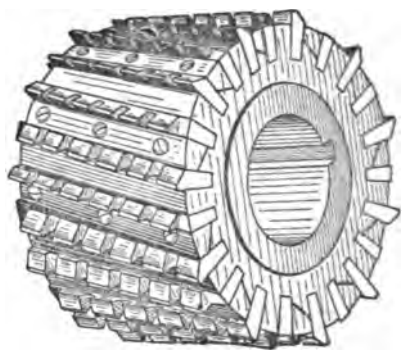


Fig. 187.

After hardening, the teeth may be put in place and fastened; they are now ready for grinding. The emery wheel for grinding milling machine cutter teeth should be of the proper grade as to hardness and coarseness; if the wheel is very *hard* or *fine*, it will be likely to draw the temper at the cutting edges of the teeth; the emery should not be coarser than No. 60 or finer than No. 90.

If the face of the wheel is glazed, remove the glaze with a piece of emery wheel somewhat harder than the wheel in use; this not only removes the glaze but makes the surface of the wheel more open and less likely to glaze. The emery wheel should run *true;* its face should not exceed $\frac{1}{4}$ inch in width. Generally speaking, the softer the emery wheel the *faster* it should run, but the peripheral speed should not exceed 5,000 feet per minute.

Fastening. There are several methods for fastening the

teeth in this form of cutter, any one of which gives satisfaction if the work is well done.

The method illustrated in Fig. 186 is in use in the works of the Pratt and Whitney Co., of Hartford, Conn. In this design, between every second pair of teeth a hole is drilled and reamed taper to receive the taper pins A A, after which the slots B B are cut with a thin cutter. After the cutters are in place the taper pins A A are driven into the holes, thus locking the cutters. To remove the cutters the pins are driven out.

A method of fastening the cutters which are used by the Morse Twist Drill & Machine Co., of New Bedford, Mass., is shown in Fig. 187. In this case the stock between every second pair of teeth is milled away not as deep, however, as the slots for the cutters. Wedge-shaped pieces of steel are fitted between the teeth as shown. When these are drawn to place by means of fillister headed screws they bind the cutters very securely. If the wedge-shaped binding blocks do not touch the bottoms of the slots they will not hold the cutters securely in place.

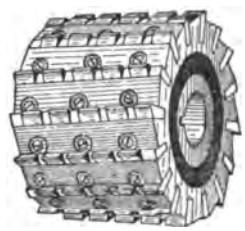


Fig. 188.

The method shown in Fig. 188 is used by Brown & Sharpe Mfg. Co. of Providence, R. I. The teeth are held in place by taper bushings and screws as shown.

Standard Key Ways. To prevent milling machine cutters turning on the arbor when cutting, it is necessary (especially when taking heavy cuts) to have key ways cut as shown in Fig. 189.

The arbor, of course, must have a similar slot to receive the key. It will be noticed that the dimension D refers to the diameter of the *hole* in cutter, and not to the diameter of the *cutter*.

Formed Cutters. As used by the Brown & Sharpe Mfg. Co., the term "Formed Cutter" applies to the cutters with teeth so relieved that they can be sharpened by grinding without changing their form. However, the term "Formed Cutter" can be applied to any cutter cutting a form regardless of the manner in which the teeth may be relieved. Fig. 190 represents a formed cutter.

Formed cutters are used in many shops where work of irregular shape is milled in large quantities, as in sewing machine, gun and bicycle shops.

While this style of cutter can be made to better advantage in a shop equipped with machinery designed especially for this class of work, an ordinary engine lathe can be converted to a *backing-*

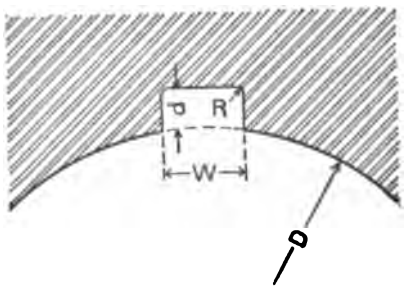


Fig. 189.

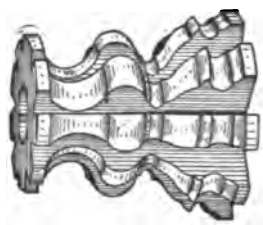


Fig. 190.

STANDARD KEY WAYS FOR CUTTERS.

Diameter (D), Inches.	Width (W), Inches.	Depth (d), Inches.	Radius (R), Inches.
$\frac{3}{4}$ to $\frac{9}{16}$	$\frac{3}{32}$	$\frac{3}{64}$	.020
$\frac{5}{8}$ to $\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	.030
$\frac{15}{16}$ to $1\frac{1}{8}$	$\frac{5}{32}$	$\frac{5}{64}$	.035
$1\frac{3}{16}$ to $1\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{32}$	.040
$1\frac{7}{16}$ to $1\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	.050
$1\frac{13}{16}$ to 2	$\frac{5}{16}$	$\frac{5}{32}$	.060
$2\frac{1}{16}$ to $2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$	.060
$2\frac{9}{16}$ to 3	$\frac{7}{16}$	$\frac{7}{16}$	.060

off lathe for relieving or backing off the cutters. Or, a comparatively inexpensive fixture (known as the Balzar backing-off device) may be used. However, a simple arrangement consists of an eccentric arbor operated by a hand lever, or a stud may be screwed in the faceplate of a lathe; the cutter is placed on this stud in a position that allows the teeth to be given the necessary amount of clearance. When backing off the teeth of cutters whose faces do not exceed 1 inch in width the Balzar backing-off fixture shown in Fig. 191 can be used to advantage. This device

is held between the centers of a lathe in the ordinary manner, the backing off being such that the cutter can be ground without alteration of shape. The tool is so constructed that it is only necessary to place the cutter upon the arbor in the ordinary way. Place the arbor on the lathe centers as shown, start the lathe and feed the forming tool in by the cross-feed screw in order to take

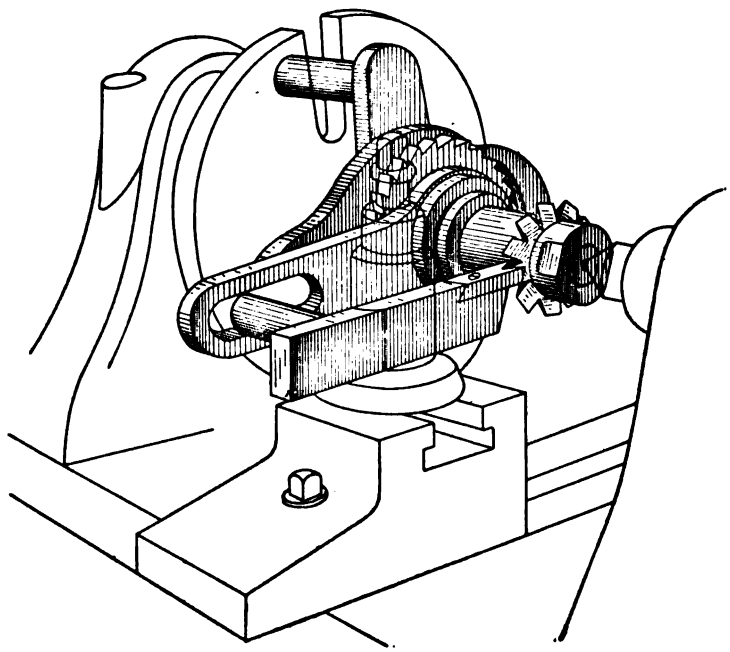


Fig. 191.

the desired cut in the same manner as in plain turning. The ratchet connected with the arbor, and actuated by the pawl, contains ordinarily thirty-six teeth and the stroke can be set to back off a cutter with 9, 12, 18 or 36 teeth.

Backing off by an Eccentric Arbor. An arbor may be made having a pair of centers located to give the cutter tooth the required amount of clearance; such an arbor is shown in Fig. 192. The eccentric centers are shown at the sectional portions at the ends. The amount of eccentricity depends somewhat on the size

of the cutter to be backed off; but for cutters not exceeding 4 inches diameter, from $\frac{5}{16}$ to $\frac{1}{4}$ inch will give excellent results.

The screw at the end of the arbor should be of a fine pitch; about 12 threads per inch for arbors 1 inch diameter. The object in cutting a fine pitch thread is, the cutter being backed off may

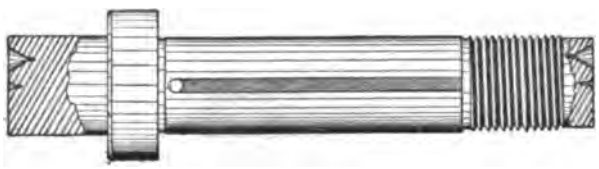


Fig. 192.

be held more securely with the same amount of power exerted in tightening the nut; again the depth of thread is not as great as for a thread of coarser pitch, and as a consequence, the plane portion at the end of the arbor (which is made the size of the bottom of the thread) may be left large enough to get in a center hole of good size having $\frac{1}{4}$ inch eccentricity.

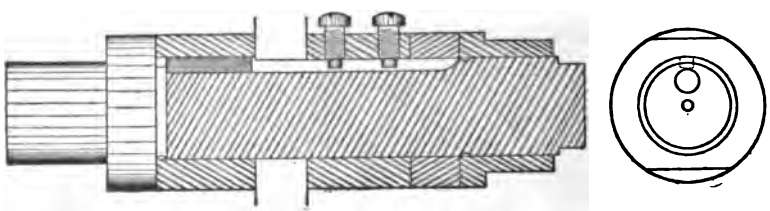


Fig. 193.

The spline cut should be at least $\frac{1}{8}$ inch wide and about $\frac{1}{8}$ inch deep; the walls of the cut should be parallel in order that the screws shown in Fig. 193 as passing through the collar and entering the slot in the arbor, may have a good bearing. These screws are to keep the collar from turning when the necessary power is applied to the nut when fastening the cutter in place. The collar on the opposite side of the cutter has a spline cut the same width as cut in the arbor, and is held in position by a spline as shown. The cutter cannot be held by a spline as it is necessary to move it each time a tooth is brought into position for backing off.

When machining the cutter blank, it is given the desired shape by means of a forming tool. If the shapes vary much in size the shape may be roughed out before using the forming tool. After it has been machined to the desired size and shape, it may

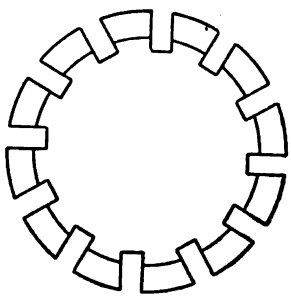


Fig. 194.

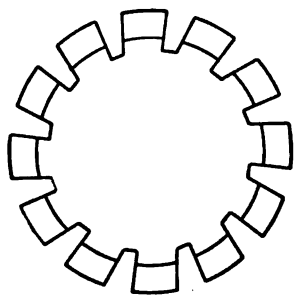


Fig. 195.

be placed between the centers of the milling machine, and a number of grooves cut the entire length of the cutter. The number of grooves must correspond to the number of teeth the mill is to have; these grooves cannot be cut to finish width until after the teeth are backed off, because the forming tool cuts a trifle deeper at the point of contact, making it necessary to mill a small amount from the face of the tooth after backing off. The grooves are sometimes cut with a thin milling cutter, or a metal slitting saw $\frac{1}{8}$ inch thick. When a groove of this description is cut, the cutter has the appearance shown in Fig. 194. Cutting a groove of this form makes more work for the operator than when cut as shown in Fig. 195, in which the distance across the rows of the teeth is decreased by using an angular cutter of the shape shown in Fig. 196. After cutting the grooves the cutter may be placed on the eccentric arbor which is held between the centers of the lathe in the ordinary manner. A forming tool that will produce the desired shape of tooth is placed in the tool post; the top face of the tool must be set at the exact height of the center of the lathe in order to produce the proper shape. Fig. 197 shows an eccentric arbor

Fig. 196.

in a lathe in position to back off the teeth of a formed mill. The arbor is operated by means of the lever. The arbor is entirely independent of the spindle in its action, the eccentric centers being placed on the centers of the lathe, and the necessary motion given by means of the lever which strikes the carriage at the end of the stroke. In order to avoid bruising the lathe a strip of leather is attached to the lever as shown.

To set the cutter tooth in the proper location before backing

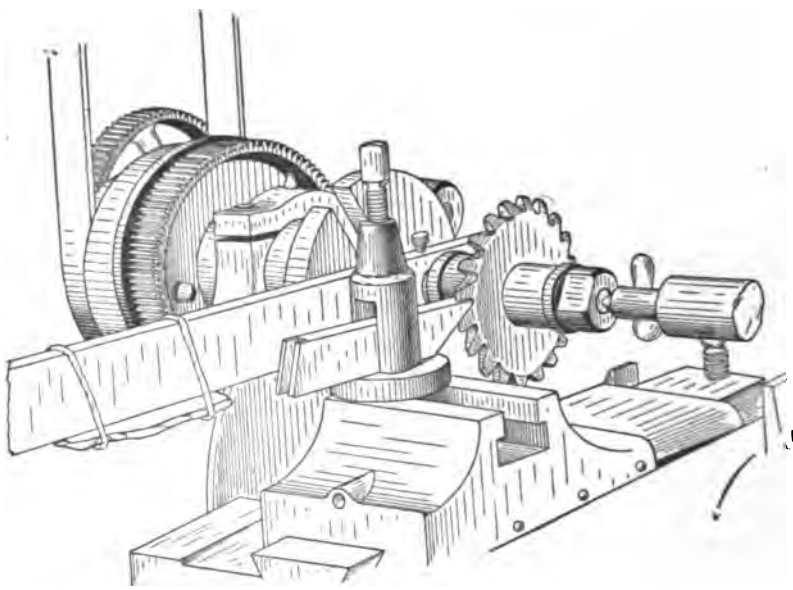


Fig. 197.

off, a piece of thin sheet metal is placed on the top face of the tool, as shown in Fig. 198. The lever is brought down on to the carriage, the tooth of the cutter is brought down on to the sheet metal and the nut tightened. The tooth to be backed off is the one below that set to the thickness of the strip above the tool. The object in raising the tooth a given distance above the face is to prevent the one being backed from and striking the tool at the end of stroke. Again the teeth are set alike. This operation must be repeated for the setting of each tooth before backing off. The forming tool is fed by means of the cross-feed screw, a tooth

Representative Types of Gang Cutters.
(Shown by Courtesy of the Morse Twist Drill and Machine Company.)

is backed off nearly the desired amount leaving a little for a finish cut; the tool is withdrawn, the nut loosened and the cutter turned on the arbor to bring the next tooth in position to be backed off. This operation may be repeated until all the teeth are backed off alike. The amount of backing off must be determined by the cross-feed stop, or a graduated dial on the cross-feed screw. After the roughing cut has been taken on all the teeth, the forming tool may be sharpened by grinding, or by oil stoning, and the finish

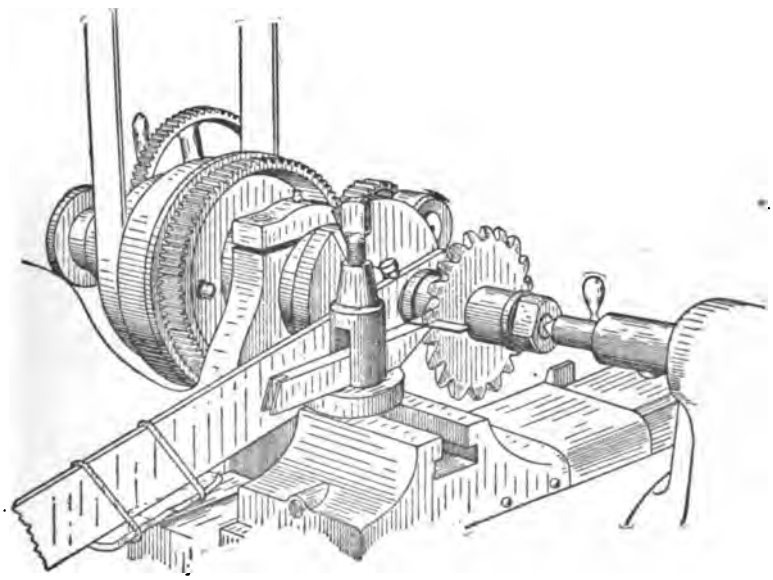


Fig. 198.

cut taken on the teeth. Another method of backing off cutter teeth is shown in Fig. 199. A stud is screwed in the faceplate of a lathe near the outer edge as shown. The cutter which must be a fit on the stud is clamped by means of the nut shown. The finger A is movable in the slot in the stationary block B which is located on the face plate to bring the tooth to be backed off in its proper location, and keeps it from turning when being operated on. The forming tool is fed in gradually until the tooth is formed. The finger is then disengaged from the space in the cutter, which is revolved by means of the set screw until the next is in position.

Each tooth is machined seperately, that is, the forming tool is fed in the required distance for each tooth when it is in position. The cutter is turned until the next tooth is in position, and the process repeated until each tooth has been backed off.

In backing off cutters in this device it is necessary to cut the notches (spaces between the teeth) somewhat wider than the teeth.

When backing off the teeth for clearance by any of the means described, it is first necessary to form the blank, then gash it or cut the notches as described; the teeth are now backed off.

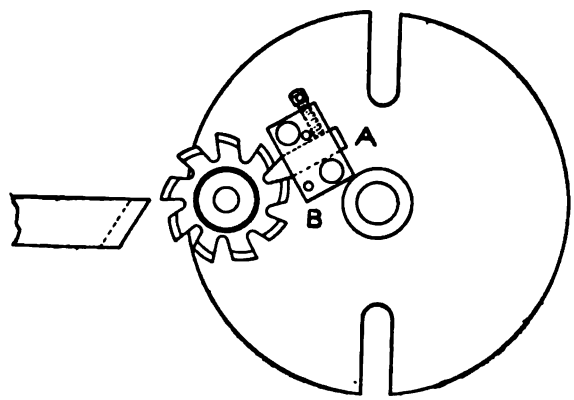


Fig. 199.

After backing off it is necessary to mill the face of the tooth back $\frac{1}{32}$ inch or so to cut away "the jump" (as it is termed) caused by the forming tool drawing in a trifle when it first strikes the edge of the tooth.

Threaded Holes. It is often necessary to make milling cutters with threaded holes. This happens in the case of *small* angular cutters, and many styles of cutters for use on profiling (edge milling) machines.

The same general instructions for making the other forms of cutters apply to those with threaded holes, except that instead of reaming the hole to a given size the thread is cut with a tap of the proper size and pitch or it is chased in the lathe. After threading, the cutter should be screwed on to a threaded arbor.

Fig. 200 shows an arbor of this description. The end A is threaded slightly tapering for short cutters about .002 inch in 1 inch of length. On the taper end of the arbor a thread should be cut of a size that will not allow the cutter to screw on the arbor quite the entire length, that is, the cutter should overhang the threaded

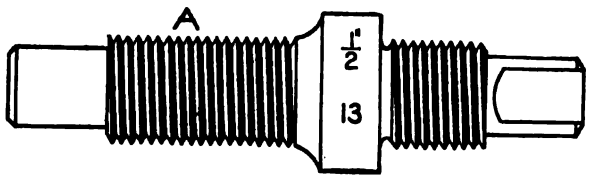


Fig. 200.

portion of the arbor a trifle (say one thread); this allows the outer end to be squared up without mutilating the threads on the arbor. The reason for using the *taper* end of the arbor when squaring the first end of the cutter is that the shoulder is true with the thread in the cutter. After squaring this shoulder, the cutter blank may be removed and placed on the opposite end of

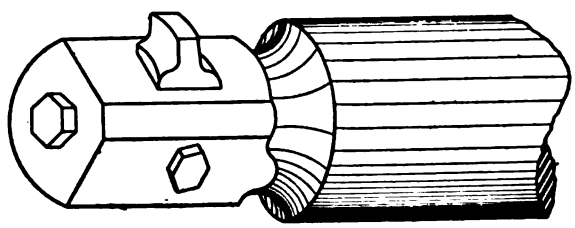


Fig. 201.

the arbor with the side that has been squared against the shoulder of the arbor. This method of machining pieces of work having a threaded hole, where it is desirable that the outer surfaces be true with the hole, is applicable to all classes of work. The cutter may be machined to length and shape on the straight end of arbor.

Fly Cutters. The simplest form of milling machine cutter is known as a fly cutter. It has only one cutting edge but is

particularly valuable when making but one or two pieces of a kind for experimental work, and when making and duplicating screw-machine and similar tools of irregular shape.

As these cutters have but one cutting edge, they produce work very accurate as to shape, but cut very slowly and do not last as long as those having more teeth. However, they are used on *special work* on account of the small cost of making. It is necessary to hold the cutters in a *fly cutter arbor* which is shown in Fig. 201.

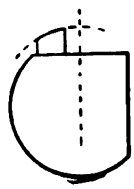


Fig. 202.

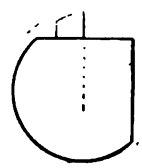


Fig. 203.

The cutter to be used in a fly cutter arbor may be filed to a templet, giving the necessary amount of clearance in order that the back edge, or keel, may not drag. If it is desirable to make the impression in the fly cutter with a milling cutter of the regular form, the piece of square steel from which the cutter is to be made may be held in the milling machine vise and the shape cut with the milling cutter. The desired amount of clearance may be given by holding the piece in the vise at an angle of a few degrees.

To make a fly cutter from a forming tool, the piece of steel may be held in the fly cutter arbor in such a position that the face is somewhat back of a radial line as shown in Fig. 202. After hardening the cutter may be set so that the cutting edge will be radial and the clearance will be as shown in Fig. 203.

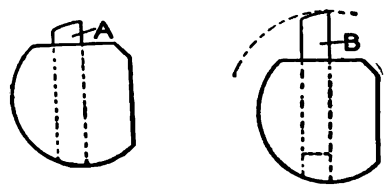


Fig. 204.

Another method of getting the clearance for the cutter is to place the top of the cutter blank as near the arbor as possible and then cut the desired shape. If the cutter is set in the arbor so that it projects from the surface it will have the necessary clearance as shown in Fig. 204. A represents the position of the blank while being cut and B the cutter in position for cutting; the dotted line showing the circle through which the cutting edge travels, the amount of clearance is apparent.

End Mills. This form of milling machine cutter (Fig. 205) is familiarly known as a **shank mill.** The term is used on account of the shank B which in small milling cutters fits into a collet. This collet in turn fits the hole in the spindle of milling machine. The collet referred to is used to save stock in making the cutters as otherwise it would be necessary to use steel large enough to make a shank of the size of hole in the spindle of the milling machine.

The cutter shown in Fig. 205 is what is termed a *left hand* mill; if the teeth run in the opposite direction, it is called a *right hand* mill.

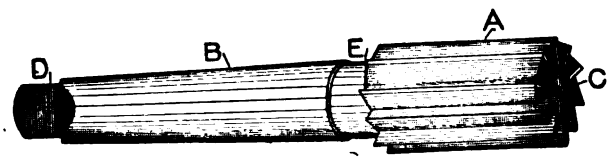


Fig. 205.

In making a shank (or end) mill of the form shown in Fig. 205 stock should be selected enough larger than the cutting end A to allow of turning off the decarbonized surface of the steel. After facing the ends to length, and turning the roughing chip, the end A may be run in the steady rest of the lathe and the center cut away — or recessed — as shown at C. The blank should be recentered and countersunk to furnish a center to use in turning the mill to size and shape. The object in cutting the center out as shown is to furnish a cavity for the angular cutter used in cutting the teeth on the end of the mill. Without this it would be impossible to grind satisfactorily.

After recentering the end C, the tenon D may be turned to size and milled to thickness, which should be a trifle ($\frac{1}{32}$ inch) less than the width of the center key slot in the collet. The taper at B should be turned enough larger than finish size to allow for grinding after the milling cutter is hardened. The cutter end A should be turned .010 inch larger than the required diameter. The portion E should be turned $\frac{1}{32}$ inch smaller than the large end of B or to dimensions if any are given on the drawings.

In order to insure teeth strong enough to resist the strain of cutting, an angular mill should be selected that will give the required shape. In Fig. 206 is shown a form of cutter tooth too weak for actual service; this tooth is the result of using an angular cutter with a cutting face forming an acute angle with the side. Fig. 207 shows a cutter whose teeth are strong, yet deep enough to be practical; these teeth were cut with an angular mill of less angle. Fig. 208 represents a cutter whose teeth were cut

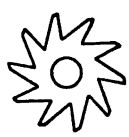


Fig. 206.

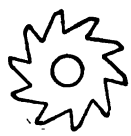


Fig. 207.

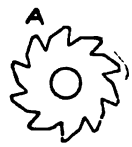


Fig. 208.

Fig. 209.

with the same cutter used for Fig. 206. The teeth were cut to the required depth first; this of course leaving them too thick at the cutting edges as shown in Fig. 209. After cutting the teeth as shown at A, Fig. 209, the index head was turned sufficiently to cut the teeth as shown at A, Fig. 208.

After cutting the teeth around the circumference of the mill,

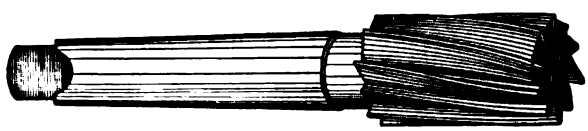


Fig. 210.

it should be placed in the collet and the collet put in the spindle hole in the spiral head in order to cut the teeth on the end.

When cutting the teeth on the end of the mill, the spiral head is turned until the cutter is in a horizontal position. The angular cutter used should not have a very acute angle or the teeth will be weak. An 80° angular milling cutter will be satisfactory.

Spiral End Mills. It is sometimes advisable to cut the teeth of end mills spiral as shown in Fig. 210. As there is no support

at the outer end of this form of mill it will be necessary to cut the teeth of a spiral that will have a tendency to force the mill into the collet rather than draw it out. Fig. 210 represents a left hand end mill cut with a right hand spiral.

End Mills with Center Cut. This form of End Mill is useful when it is necessary to cut into the work with the end of the

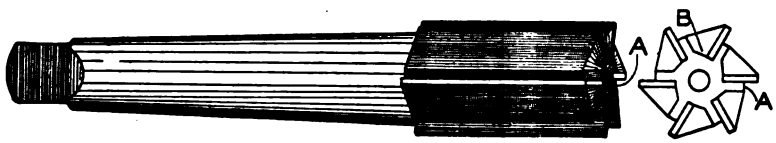


Fig. 211.

mill, and then move along as in dies, cams, and grooves. The teeth being sharp on the outside, cut a path from the point of entrance. The coarser teeth allow a heavier cut, especially in cast iron. Fig. 211 shows two views of an end mill with center cut.

After cutting the teeth on the end with an angular cutter, a

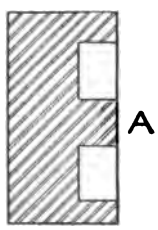


Fig. 212.

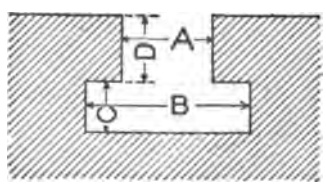


Fig. 213.

thin straight faced cutter of small diameter should be run through close to the face of the cutter tooth making a cut as shown at A; this cut should be of sufficient depth to permit of backing off the inner edge of the tool as shown at B. This clearance allows the mill to cut away the slight projection left in the center of mill when it is fed into a piece of work. Such a projection is shown at A in Fig. 212.

T-Slot Cutters. In cutting T slots in various parts of machines, such as milling machine carriages, etc., it is necessary

to use a form of shank mill known as a T-Slot Cutter. Fig. 213 shows the ordinary form of T-slot; while Fig. 214 shows the cutter. A portion of the stock below the teeth is cut away as shown at A A in the sectional view Fig. 215. This is necessary in order to back off the teeth on the sides of the cutter for clearance, and to do away as far as possible with unnecessary friction when the cutter is working.

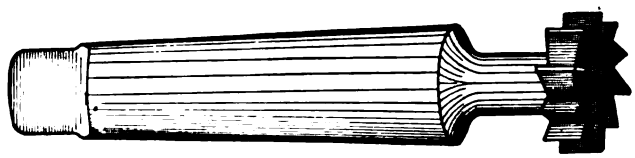


Fig. 214.

T-slot cutters are usually made $\frac{1}{32}$ inch larger in diameter than the size designated on the cutting portion to allow for sharpening; that is, a mill intended for cutting a slot $\frac{1}{2}$ inch wide is made $\frac{1}{2} + \frac{1}{32}$ or $\frac{17}{32}$ inch diameter, unless intended for cutting a slot to given dimensions.

It is advisable to harden mills of this description the entire length of the neck, especially if the neck is of small diameter; otherwise they will be very likely to spring when in use. After hardening, the neck should be drawn to a blue color, while the cutting part should be drawn to a straw color.

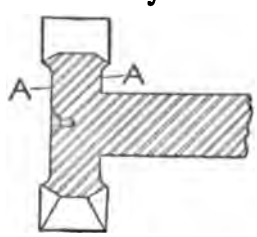


Fig. 215.

When grinding end mills, the shank in all cases should be ground first to fit the collet or holder, allowing it to enter *far enough* to key out readily, yet not enough to allow the shoulder above the tenon to strike the shoulder in the collet.

After grinding the teeth for clearance on the diameter, the teeth on the end should be ground. Most universal and cutter grinders are provided with a fixture for holding the mill by the shank while grinding these teeth; such a fixture is shown in Fig. 216.

Face Milling Cutters. This form of cutter is used in milling surfaces too large to be cut with the ordinary form of milling

cutter held on an arbor passing over the work. As the full diameter of the face of the cutter may be used, it may have less than one half the size that would be necessary for a side milling cutter. A side milling cutter must be double the diameter of the surface to be cut plus the diameter of the collar on the arbor. For instance if a surface as A, Fig. 217, were to be milled, it would be necessary to use a cutter somewhat larger in diameter than twice

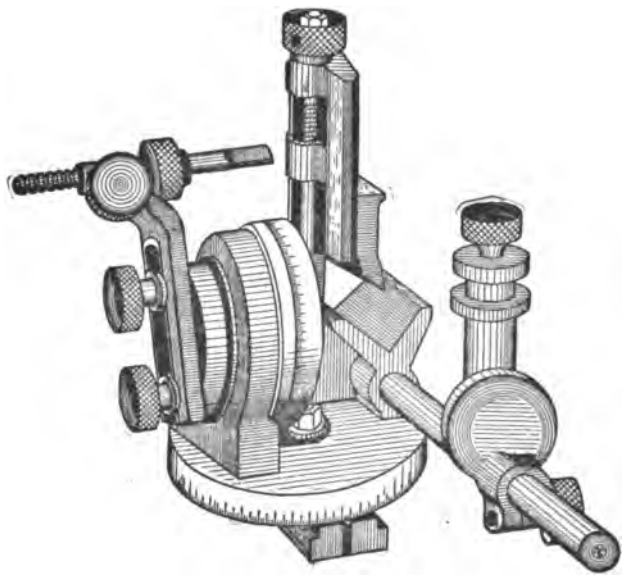


Fig. 216.

the height of the surface plus the diameter of collar B. Whereas if a *face* milling cutter of the form shown in Fig. 218 were used the diameter need not be much greater than the height of the face of the piece of work being milled.

Generally speaking, cutters of this description are necessarily of a diameter that makes it advisable to use inserted teeth as shown in Fig. 218. The body may be made of cast iron, having a taper hole and key way, and held in place on the arbor by a screw.

The teeth may be made of tool steel and hardened, or of self-hardening steel if the cutter is to be subjected to rough usage. In

either case they may be fitted to the slots by grinding on a surface grinder, and held in place by taper bushings and screws as explained under "Milling Cutters with Inserted Teeth." The construction of the body may be readily understood from the sectional view given in Fig. 219. The letters A, B, and C represent the diameter of cutter, width of face, and number of taper of the hole respectively, while D represents the key way.

The following table gives the dimensions of Face Milling Cutters of different diameters.

FACE MILLING CUTTERS.

A	B	C
5½″	2 ″	No. 10 Brown & Sharpe Taper.
6½″	2 ″	" 12 " " " "
7½″	2 ″	" 12 " " " "
8½″	2½″	" 12 " " " "
9½″	2½″	" 12 " " " "

After boring and reaming the taper hole, the body of the cutter may be placed on a taper mandrel fitting the hole, and the ends and circumference finished to size. It should then be placed in the vise on the shaper or planer at the proper angle and the spline slot cut of an equal depth at each end of the taper hole. After removing the burrs it should be placed between the centers on the milling machine, and the slots cut for the teeth.

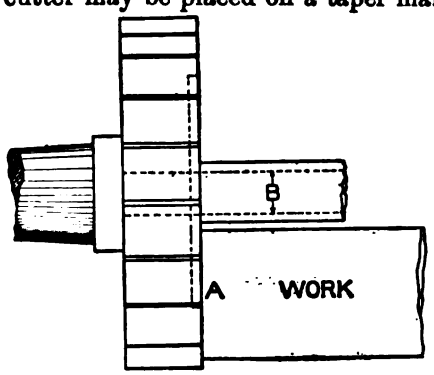


Fig. 217.

When the teeth are firmly secured in their proper places, they may be ground for clearance; the same general instructions given for grinding other forms of milling machine apply to this form.

Arbors For Face Milling Cutters. In. Fig. 220 is shown an arbor to be used in connection with *face* milling cutters. The

shank A fits the hole in the spindle of the milling machine. B is the body which fits the taper hole in the cutter; this portion of the arbor has a spline which fits a spline slot in the cutter. A screw C enters the body of the arbor and is used in holding the cutter

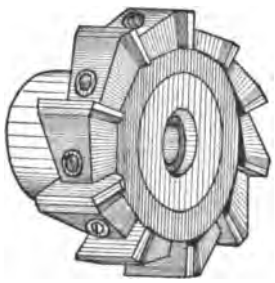


Fig. 218.

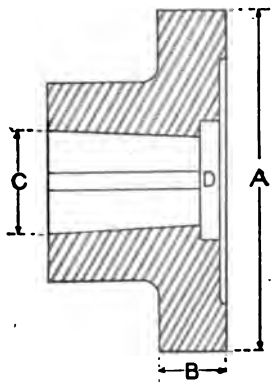


Fig. 219.

on the arbor. D is a nut used to force the cutter off the arbor when it is necessary.

Stock used in making an arbor for a face milling cutter should be strong and stiff, and on this account tool steel is generally used. After squaring the end and roughing out the cir-

Fig. 220.

cumference, one end should be run in the steady rest and the screw hole in the end drilled and tapped, after which it should be countersunk at the end to furnish a center for use in turning and finishing. The tenon should now be turned to size and milled to thickness. If necessary the end of the tenon should be hardened before finish turning the arbor to prevent springing when heating. After turning the taper to fit the hole in the milling

machine spindle, and on the opposite end to fit the cutter, the thread may be cut for the nut D, Fig. 220, after which the arbor may be cut for the spline as already explained.

The result will be more satisfactory if the two tapers are left a trifle large until after cutting the spline cut and are then ground to fit. Although the spline is intended to fit snugly in the slot in the arbor, the fit should not require pressure enough to endanger the truth of the arbor when it is pressed to position.

DRILL JIGS.

A drill jig is a device for holding work so that one or more holes may be accurately drilled; the locations of the holes may be governed by hardened bushings (guides) through which the drill run.

The design of a jig depends entirely on the shape of the piece and the nature of the work to be done. Jigs should be so designed that work may be placed in and taken out of them as quickly as possible. The fastening device should allow rapid manipulation, yet be capable of holding the work without danger of a change of location.

The construction of drill jigs calls for as great accuracy as any branch of the tool-maker's business; but no undue accuracy should be indulged in. If the location of a hole is near enough when within a limit of variation of $\frac{1}{16}$ inch it is a waste of time to attempt to get it within .0005 inch. Yet if the work is of such character that it is necessary that the holes be within a limit of variation of .0001 inch or even closer, every effort should be made to locate the drill bushings as accurately as possible.

While the design of the jig and the character of the work to be drilled must necessarily determine the method of construction, a few general points may not be amiss. The amount of *finish* given the exposed surfaces of a jig must be determined by the custom or requirements of the individual shop. In many shops it is not considered necessary nor advisable to finish the surfaces any more than to allow of their being wiped without the waste sticking to the jig.

A jig should be constructed so that it may be easily cleaned. Chips or dirt between the piece of work and the seating surface,

or between the work and the stops, or locating points, throw the work out of true. As a result the holes will be at a wrong angle to the working surface, or they will be improperly located. Either condition would make the pieces unfit for use on most work, consequently bearing surfaces (wherever possible) should be cut away leaving several small seating surfaces, rather than one large one. A, Fig. 221, shows a piece of work resting on its entire seating surface; while B shows a surface cut away to leave six bearing points. If the seating surface is to be cut away as described, the raised portions should be so located that the article

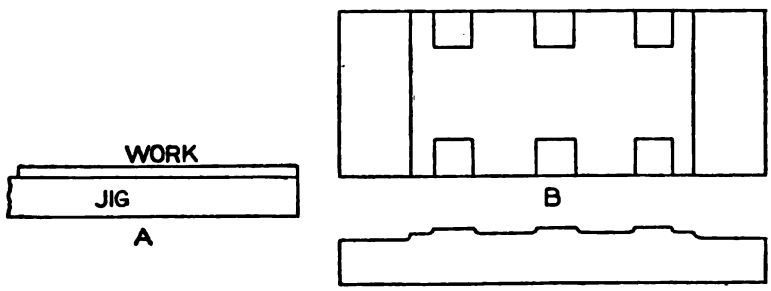


Fig. 221.

cannot be sprung by the action of the cutting tools or from any pressure that may be applied by any fastening device; otherwise the work will be thrown out of true as badly as though chips were lodged between the work and the seating.

It is advisable, whenever possible, to divide a long, locating bearing into several short surfaces, thus decreasing the chance of holes becoming inaccurately located. When making jigs for pieces that are likely to have burrs at any given point, it is well to cut a depression in the seating or locating surfaces for the burr to set in, thus preventing the work being incorrectly located.

Seating surfaces should be made smooth so that chips and dirt may not stick to them, but they should not be polished nor finished as this would necessitate unnecessary cost and might cause the surface to get out of true.

A jig must be handled by the workman, and a clumsy jig cannot be handled as readily as one designed so that the workman can use it to advantage.

Sharp corners should be avoided wherever possible, and all handles or similar devices should fit the hand. If not, the amount of work done will not be the maximum, as the operator cannot do as much work with a jig which tires the hand and wrist.

As already stated the accuracy with which a jig should be constructed depends entirely on the nature of the work to be done, yet it should be borne in mind that any inaccuracy must of necessity be duplicated in the work.

EXAMPLES OF JIGS.

A few designs of jigs will now be considered to show the general requirements and the methods of construction.

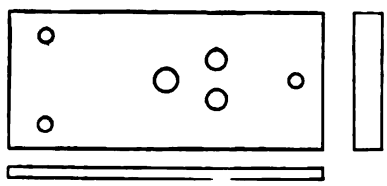


Fig. 222.

The slab jig, shown in Fig. 222, is the simplest form in use; it consists of a piece of flat stock of suitable thickness and of the same general outline of the piece of work to be drilled. The work may be clamped to the jig by means of U clamps, or parallel jaw clamps. If the jig is made of machinery steel the walls of the holes may be case-hardened by heating the jig red hot and sprinkling powdered cyanide of potassium around the hole, reheating in the fire and plunging in water; it should be worked back and forth in the bath so that the water will circulate through the holes. While this form of jig answers very well where but a few pieces are to be drilled, it is not suitable for permanent equipment on account of the wear of the holes. To overcome this, the holes may be made sufficiently large to receive hardened bushings having holes the size of the drill to be used. Fig. 223 shows this construction.

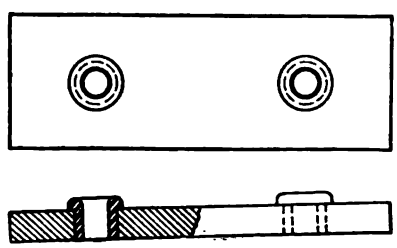


Fig. 223.

When holes are to be drilled at certain distances from one or

more edges, it is necessary to have stops against which the work may rest. These stops may be pins, a shoulder, or a rib.

If the outline of the work has been finished by any process — as milling, punching or profiling — that insures uniform lengths and widths, the locating points may be placed on all sides of the piece as shown Fig. 224, in which pins are used as stops or locating points. It is necessary to flatten the pins on the sides that come in contact with the work to prevent wear.

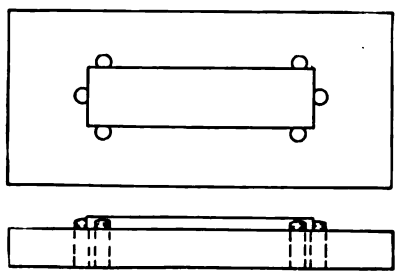


Fig. 224.

When a jig is to be used constantly, it is advisable to have a shoulder or rib for the work to rest against, rather than pins, as the former will not wear as rapidly. Fig. 225 shows the same form of jig as Fig. 224 except that ribs are substituted for pins.

When there is no surety that the dimensions of the different pieces are exactly alike it is advisable to locate the pieces in the jig from certain portions. The work must be forced against the locating points by means of a screw, cam or wedge. With a screw the work may be forced to position and held there even when the dimensions of the piece vary considerably. The cam is operated much more quickly than the screw and holds the work firmly when the size of the pieces vary but little. For certain purposes the wedge is an admirable holding device, but it is not generally used. Fig. 226 shows a jig in which the work is located from one side and end; the work being forced against the stops by means of a screw.

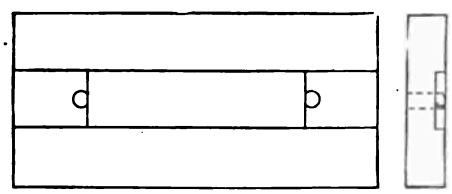


Fig. 225.

Fig. 227 represents the same jig having a cam instead of a screw.

When making any of these styles of jigs, the holes to contain the bushing may be located by several methods. If extremely accurate work is not necessary, a templet may be made, or a model

piece used having the holes properly located; this piece may be placed in the jig and by means of drills the holes are transferred to the jig. If the bushings are to be used the holes may be enlarged by a counterbore having a pilot which fits the drilled hole and a body of the desired size of the bushing. While this method is cheap and good enough for certain classes of work, it is not advisable to use it for a very accurate job.

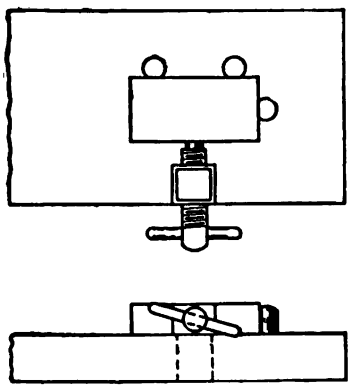


Fig. 226.

Another inexpensive method which insures *fair* results is to drill the holes as described above, then run a drill or reamer a trifle larger than the holes in the templet through the holes in the jig. Now place the templet in position and by means of a counterbore having a pilot which fits the hole in the templet counterbore the jig to the templet as shown in Fig. 228. Better results will be obtained if the ends of the teeth of the counterbore are made of the shape shown in Fig. 229, especially if the drilled hole should have run from its proper location.

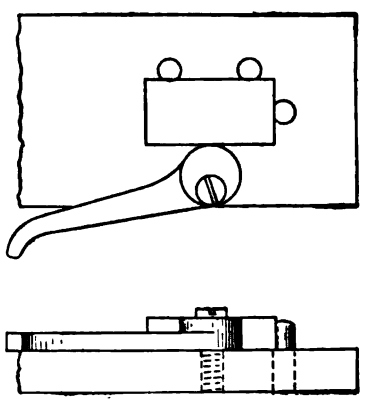


Fig. 227.

A third method is used when the bushing holes must be located by measurement, or when there is no templet or model piece. By means of a surface gauge having the point of the needle set at the proper height from a scale attached to an angle iron, as shown in Fig. 230, scratch a dimension line on the surface which has been colored with blue vitriol. The needle is first set to the height of the locating rib. The scale attached to the angle

iron is adjusted so that the needle is at the exact height of one of the inch lines if possible, if not, at one of the half of quarter inch lines. The needle may then be raised to locate the center of the first hole and a line scratched while the jig is on edge. The centers of the other holes may now be laid off on this plane, after which the jig may be turned one quarter way around to

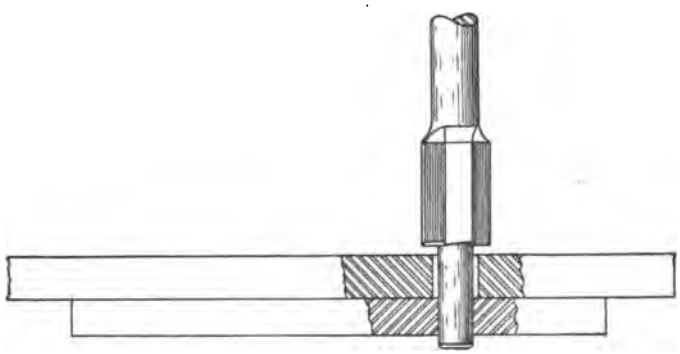


Fig. 228.

locate the hole from the other measurements. Where the lines intersect prick punch the surface of the jig. For this work *do not* use the center punch made for centering work to be turned in the lathe. Use the prick punch which should be much lighter than the ordinary center punch; Fig. 231 shows the two punches. The point of the prick punch should be ground in some form of

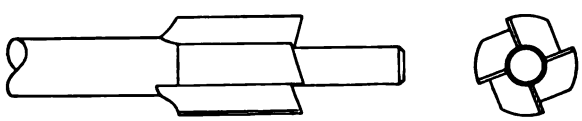


Fig. 229.

grinder in which it may be held and revolved in order that the point may be perfectly round. If this is not done it will be impossible to get the point of the center indicator to run true when attempting to true the jig on the face plate of the lathe.

While the above method might be properly classed as an approximate measurement, an experienced workman can locate the bushings within a small limit of variation. More accurate

work will result if the height gauge is used in laying off the dimension lines. The bottom surface of the extension is set to the height of the locating rib, as shown in Fig. 232; then by means of the vernier it may be raised to the exact height of the

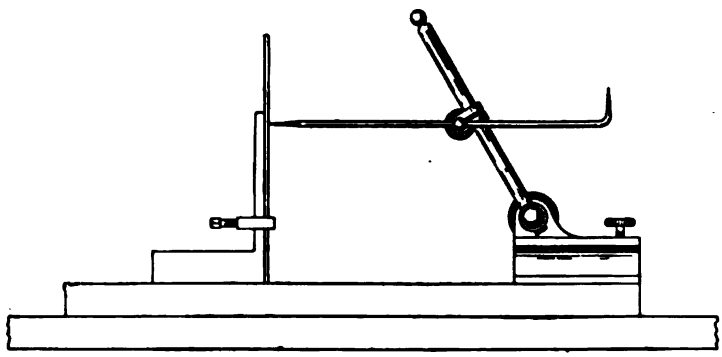


Fig. 230.

dimension desired, and the line scribed by means of the point of the extension.

While this method insures greater accuracy in laying off dimension lines and is sufficiently accurate for most work, it is open to the objection that the tool maker may change the location of centers somewhat when prick punching.

When *precise* measurements are desired many tool makers

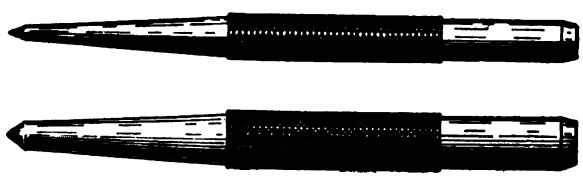


Fig. 231.

determine the location of bushing holes by means of hardened discs or buttons. A very common size, Fig. 233, if $\frac{1}{2}$ inch diameter, $\frac{3}{16}$ inch thick and having $\frac{1}{4}$ inch hole. While it is not essential that the diameter be any particular size, it must be some fraction divisible by two without a remainder, as one half the size of the disc is considered in all computations. If the disc is .500

inch diameter, .250 inch is the decimal to be considered; but if the disc were $\frac{9}{16}$ (.5625) inch diameter it would be necessary to consider the decimal .28125 in all computations. In locating the disc most of the measurements are made with the vernier caliper, and as the tool is not graduated to read closer than .001 inch it would be impossible to consider the fractions of a thousandth of an inch; consequently discs .500 inch diameter are generally used.

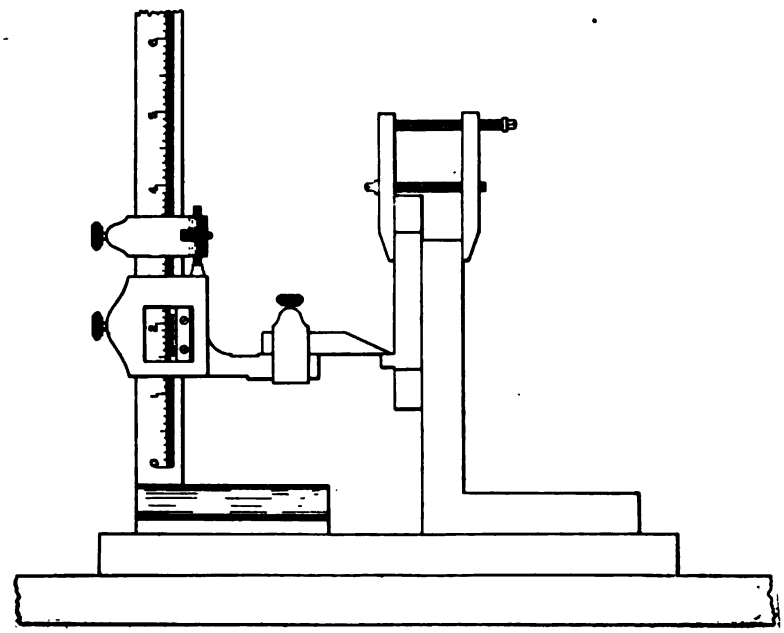


Fig. 232.

The locations of the different holes are laid off by means of the surface gauge, setting the needle to the scale fastened to an angle iron as already described. The holes are drilled and tapped for a screw somewhat smaller than the hole in the discs. The discs are now attached to the jig by means of screws. As the screws do not fill the holes in the discs, they may be moved until properly located. Fig. 234 shows a jig having the discs located in relation to the stops.

After properly locating a disc at each point where a bushing is desired, the jig may be fastened to the face plate of the lathe.

The jig must be so located on the face plate that one of the discs will run *perfectly* true. This may be determined by a test indicator operating on the outside of a button, as shown in Fig. 235. After locating so that the disc runs exactly true, the disc may be removed and the hole bored to the required size. The jig may now be moved to bring another disc to the proper location, after which it may be removed and the hole bored; this operation may be repeated until all the bushing holes are bored.

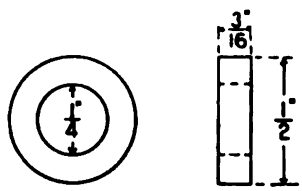


Fig. 233.

When jigs are made for permanent equipment, or if they are to be used constantly, it is well to provide some means of raising them from the drill press table to avoid inaccurate work occasioned by chips. When the jig is made of cast iron, the legs are sometimes cast solid with the jig as shown in Fig. 236. In order to grasp a jig handle in a manner that will not be tiresome to the

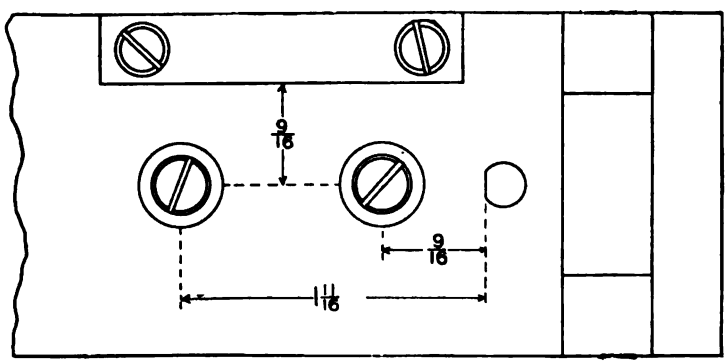


Fig. 234.

wrist or hand, and allow sufficient room between the handle and the table of the drill press so that the fingers may not be cut by chips, the legs are made of a length that will raise the handle about $1\frac{1}{8}$ inches above the table. As cast-iron legs of this length would be too weak, it is customary to make the legs of tool steel hardening the ends that come in contact with the drill press table.

While the form of jig shown in Fig. 222 would give satisfaction on certain classes of work, the process of putting the work in,

and taking it out of the jig would be very slow, as it would be necessary to clamp the work securely to resist the pressure of the cutting tools.

In order that work may be handled rapidly during these operations, jigs are designed so that the work will rest on the base

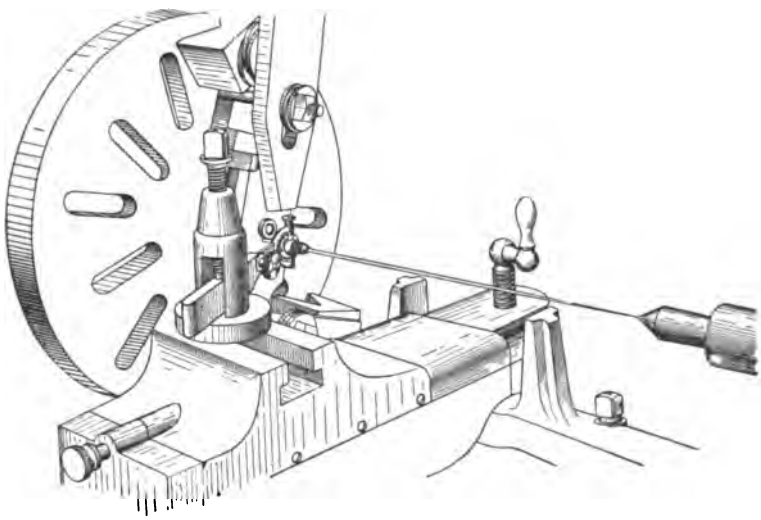


Fig. 235.

of the jig as shown in Fig. 237. A leaf or cover containing the bushings can be raised when putting the work in place and taking it out.

When the pieces to be drilled are of a uniform thickness the

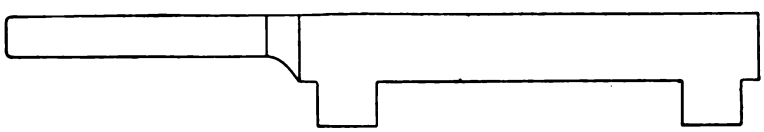


Fig. 236.

leaf may be made to rest on the piece. But should the pieces vary in thickness the leaf would not be parallel to the base; consequently the hole in the bushing would not be at right angles to the piece to be drilled. For this reason a little space is left between the top of the piece to be drilled and the bottom of the

leaf, as shown in Fig. 238; a steady pin having a shoulder is located at the handle end of the jig. The upper end of pin may project into a hole in the leaf as shown thus relieving any strain on the joint of the jig occasioned by the action of the cutting tools.

When holes are to be drilled from opposite sides of a piece

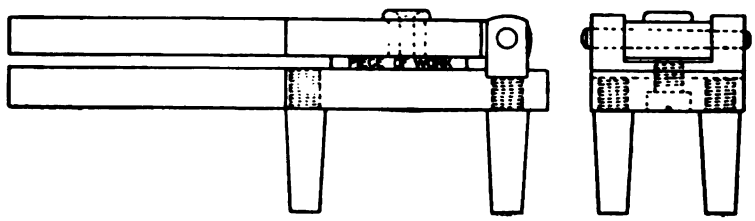


Fig. 237.

of work, as shown in Fig. 239, a jig may be constructed having legs on both upper and lower sides, but both sets of legs should be solid with the base as shown in Fig. 240.

If the two end holes in Fig. 239 are of the same size and it is necessary to use a drill press having but two spindles, the legs on each side should be of a length that would make it possible to

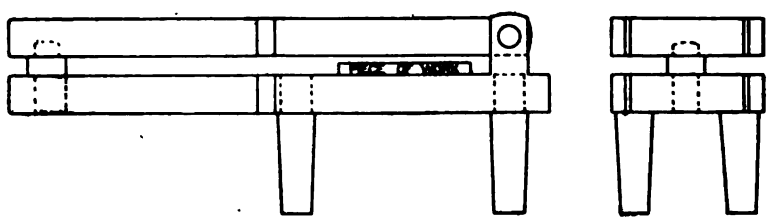


Fig. 238.

set the stops so that the drill would cut the required depth on each side. If a drill press having three or more spindles is to be used, the jig legs may be of a convenient length, as two drills of the same diameter can be used in two different spindles, each pair to drill the required depth when the stop is set.

Drill jig legs are generally made of tool steel and are screwed into the base of the jig: the thread on the legs should be a good

fit in the base. After screwing in place the ends of the legs should be machined to length by milling or planing; the legs may then be removed and the ends that come in contact with the drill press table hardened. The legs may now be polished (if that is allowable) and then screwed in place. The ends should now be ground to such a length that the surface where the work is seated will be of the correct height above the drill press table.

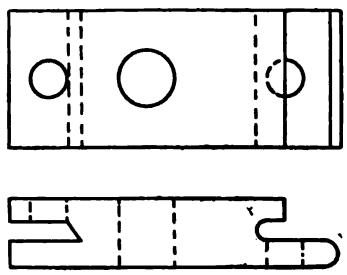


Fig. 239.

Grinding the ends of the legs can best be done in a surface grinder, or some form of universal grinder designed for surface grinding. After grinding, the ends of the legs may be lapped to

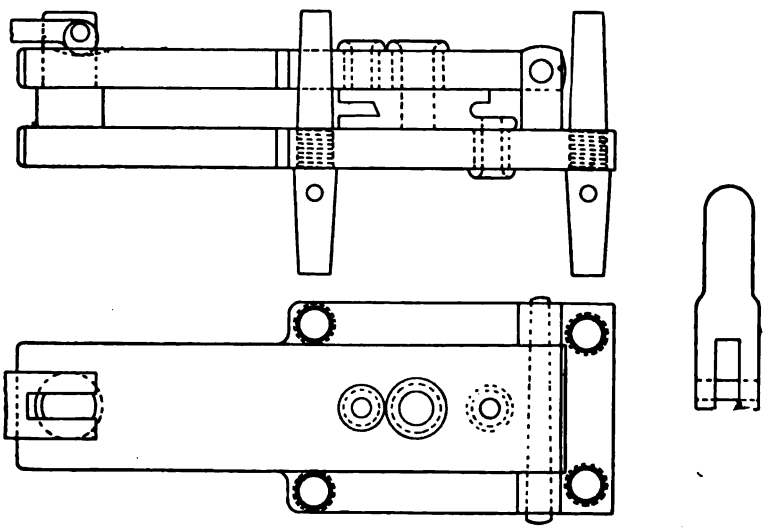


Fig. 240.

remove any irregularity that may result from grinding. A very good lap may be made from a flat plate or block of cast iron. The surface to be used may be planed flat and smooth, then a series of grooves cut to form squares, as shown in Fig. 241. These grooves may be cut with a V-shaped tool and should be $\frac{1}{4}$ inch to $\frac{1}{64}$ inch

to $\frac{1}{32}$ inch deep. The grooves catch the emery and feed it to the work being lapped. If the pressure is not equal one leg may be

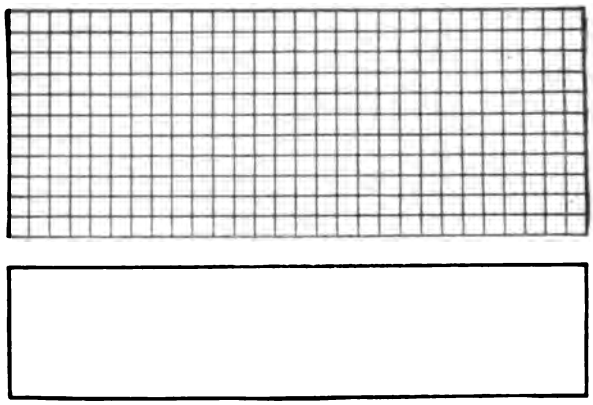


Fig. 241.

cut shorter than the other, or may be lapped out of true, causing the jig to rock.

APPENDIX

QUESTIONS IN REVIEW

The following lists of questions afford the reader a means of testing his knowledge of the subjects treated in the present volume. Any one who has carefully read the foregoing subjects should be able to answer every question accurately. The reader is advised to go through the questions thoroughly, working out his answers and checking his results with the answers given. This will afford a valuable means of fixing the matter in mind. Students who are preparing for examinations for college, civil service or engineer's license will find the questions of the greatest value.

REVIEW QUESTIONS

ON THE SUBJECT OF

PATTERN MAKING.

---

1. What woods are most suitable for small patterns?

2. What tools should be used for finishing lathe work?

3. What is the usual allowance for finishing?

4. Why can work be done more rapidly upon a band than upon a jig saw?

5. How can a solid pattern be molded so that it is imbedded in both cope and drag?

6. Why is it usually necessary to make a pattern in two parts?

7. What precaution should be taken in the preparation of the wood in making a glue joint?

8. What should be the outside diameter of the original wooden pattern for a pulley rim, the finished pulley to be 3 feet in diameter: (*a*) when measured by a common rule; (*b*) when measured by a shrinkage rule?

9. How are iron patterns usually protected from rust?

10. Should a gear wheel 16 inches in diameter have spokes or a web to connect the rim and hub?

11. What are the principal requisites of a material for patterns?

12. What are the qualifications of a pattern-maker?

13. What are the two parts of a flask called?

14. What is a face-plate?

15. How are the two parts of a round pattern held together for turning?

16. How can the setting of glue be quickened?

17. What should be the breadth of the outer ends of the spokes of a pulley whose diameter is 2 feet, 6 inches and the width of the rim 8 inches, there being five spokes?

Ans. 1.81 inches. Use $1\frac{7}{8}$ inches.

18. In the making of a pattern for an engine cylinder, what is made first?

19. What woods are in most common use for patterns?

20. What is the advantage of a sliding carriage on a turning lathe?

21. How is shellac varnish prepared?

22. Why are large patterns not made of a single piece of wood?

23. How is overheating avoided in the preparation of glue?

24. What should be the breadth of the outer ends of the spokes of a pulley, whose diameter is 3 feet, the width of the rim 10 inches, there being five spokes?

Ans. 2.08 inches or 2 inches.

25. How are engine cylinders made?

26. How should wood be inspected?

27. What will be the linear velocity of the rim of a circular saw 16 inches in diameter when running at a speed of 2,500 revolutions per minute. Ans. 10,472 feet per minute.

28. How should a saw table be equipped?

29. What are dowel pins and what are they for?

30. What is the effect of prematurely chilling the glue after it has been applied to the surface which it is desired to unite?

31. Why are patterns shellaced in two colors?

32. To what extent should a pattern maker be a draughtsman?

33. At what speed should the pulleys of a band saw revolve if they are 3 feet in diameter?

Ans. About 370 revolutions per minute.

34. Why does wood warp?

35. What is a convenient allowance for draft?

36. How should wood be seasoned?

37. How long a time does glue require to set?

38. How can a pattern that has been slightly damaged be repaired?

39. When should cores be used instead of allowing the pattern to make its own cores?

40. How many spokes $2\frac{1}{8}$ inches wide at the rim should be put into a pulley 4 feet in diameter and having a rim 9 inches wide? Ans. 5.6. Use 6.

41. How long a time is required to harden a coat of shellac varnish?

42. How is a round core made?

43. Which will dry the more rapidly, large or small timber and why?

44. How can the tendency of glued strips to curl be diminished?

REVIEW QUESTIONS

ON THE SUBJECT OF

FOUNDRY WORK.

---

1. What is the meaning of the term "wrought iron"?

2. What is a flux? When is it used?

3. What is the difference between the cope and drag?

4. What is the weight of a cast-iron plate 16 inches square and 2 inches thick with a hole 3 inches in diameter through the center? Ans. 129.79 pounds.

5. What is loam?

6. How are cores dried?

7. How is blacking applied to a mold?

8. Why should a freshly daubed ladle be dried before using?

9. What grade of pig iron contains the largest proportion of combined carbon relatively to the whole amount in the iron?

10. What is the ordinary method by which castings are hardened?

11. What are chaplets?

12. What are risers?

13. How are the arms of large gears usually moulded?

14. Why are large gears and wheels usually cast in sections?

15. To what depth does the chill in castings extend?

16. Under what circumstances are loam moulds ordinarily used?

17. What should be the diameter of the shell of a cupola 24 inches in diameter?

18. What is the bed of a charge?

19. What is the best material from which to make flasks?

20. What is the upward pressure on a cope where there are three surfaces of 16, 35 and 48 square inches submerged respectively to the depths of 15 inches, 10 inches and 18 inches?

Ans. 379 pounds approx.

21. What is the most common form of dry sand moulding?

22. What is a cope?

23. What effect does the point at which the metal enters the mould have upon the pressures exerted, by the molten metal?

24. What is the difference in appearance between graphitic and combined carbon in pig iron?

25. What effect does manganese have upon the quality of iron?

26. What is the object of using a follow board?

27. What kind of cores are used for columns?

28. How is the full width of face for a pulley obtained?

29. What is the object of using a contracting chill?

30. How are loam moulds built?

31. What should be the height of a cupola that is 44 inches in diameter?

32. What is the pressure upon the bottom of a mould 24 inches below the surface of the gate, the area being 5 feet square?

Ans. 22,524.48 pounds.

33. What is the condition of the first iron that flows from the spout after putting on the blast?

34. What effect does chilling have upon the metal of a casting?

35. How should a mould with small cores and passages be poured?

36. What effect does silicon have upon the quality of iron?

37. What are the ordinary methods that are employed for cleaning castings?

38. What is the object of feeding a mould?

39. At what point is the metal usually poured into a pulley mould?

40. What is the chief characteristic of a good chilling iron?

41. In what way are loam moulds dried, other than in a core oven?

42. What is the first work to be done in the preparation of the cupola for melting?

43. What thickness of sand should be left about the cavities of a mould?

44. What is the weight of a cast iron ball 12 inches in diameter? Ans, 235.87 pounds.

45. How many grades of foundry irons are there?

46. What effect does phosphorus have upon the quality of iron?

47. What portion of a three-part flask is called the "cheek"?

48. How is the pattern for the spokes of a pulley placed in the mould?

49. How many coats of loam are usually applied in making a loam core?

50. What should be the diameter of the shell of a cupola which is 44 inches in diameter inside the lining?

51. How are the two parts of a flask made to register accurately when brought together after the pattern has been removed?

52. Of what are cores made?

53. What is the object of using blacking?

54. What effect does sulphur have upon the quality of iron?

55. What classes of castings can be made in open sand?

56. How are pipes usually cast? Why?

57. What is skinning loam?

58. What is the weight of a cast iron plate $1\frac{3}{4}$ inches thick and in the form of a trapezoid of the following dimensions; parallel sides 18 inches and 12 inches long respectively; perpendicular distance between parallel sides 9 inches? Ans. 61.59 pounds.

59. With what class of pig iron can the largest quantity of scrap be used?

60. How are large gears usually moulded?

61. What is the object of annealing chilled castings?

62. What should be the total area of the tuyeres in a cupola: (*a*) 32 inches in diameter; (*b*) 43 inches in diameter; (*c*) 66 inches in diameter?

63. What is the weight of a cast iron plate $1\frac{1}{2}$ inches thick in the form of an equilateral triangle, each of whose sides measures 16 inches? Ans. 43.35 pounds.

64. How should a large mould of heavy section be poured?

65. What means should be taken to avoid weakening castings where changes of direction occur in the surfaces?

66. How is a pulley to be moulded whose face is to be less than that of the pattern from which it is made?

67. What are some of the more common of the impurities contained in pig iron?

68. What is the upward pressure on a cope where there are two surfaces of 90 square inches and 1 square foot, submerged 18 and 21 inches respectively below the surface of the metal? Ans. 1210.69 pounds.

69. How are the parts of a flask held in position when the metal is being poured?

70. When is a three-part flask used?

71. When is a loam mould in the best condition for blacking?

72. How is sand prepared for moulding?

73. What is the principal foreign element in pig iron?

74. How are gears moulded where a full pattern is provided?

75. What properties should sharp sand possess?

76. What should be the height of a cupola that is 56 inches in diameter?

77. What is the object of blacking a core?

78. What is the upward pressure on a cope where the exposed surface is 2 square feet and the depth 19 inches? Ans. 1426.55 pounds.

79. What is the smallest number of teeth that should be placed in a sectional gear pattern?

80. What should be the principal ingredients composing moulding sand?

81. What precautions must be taken in cooling castings?

82. What kind of moulding is most practiced?

83. Why is hay rope used on loam cores?

84. What grade of iron contains the largest proportion of graphitic carbon?

REVIEW QUESTIONS

ON THE SUBJECT OF

FORGING.

1. Why is a piece of metal nicked in order to break it when cold?

2. What is the weight of a bar of flat iron $\frac{1}{2}$ inch thick, 2 inches wide and 13 feet 6 inches long?

3. What length of 3-inch round iron must be cut off to make a truncated cone having a bottom diameter of 3 inches, a top diameter of 2 inches and a height of 8 inches?

4. What is the welding color for laying steel upon iron?

5. What is the difference between drop forging and pressing?

6. What is the best form of weld for heavy shafts?

7. What effect does hammering have upon iron and steel when properly done?

8. How is the blast created for a forge?

9. What is the use of a swage and flatter?

10. What is the scale, and how is it formed?

11. Describe the process of brazing.

12. How are the heavy pieces usually handled under the hammer?

13. What is meant by the critical temperature of steel?

14. What air pressures are used for the blast?

15. Tell what you can of casehardening.

16. How should metal be piled on a shingle for fagotting?

17. What is the weight of a wrought-iron plate $\frac{5}{8}$ inch thick, 24 inches long and 10 inches wide?

18. What will be the length of a bar of iron at a temperature of 1050° F. if it is 6 feet 3 inches long at 60°?

19. What is the controlling factor in fixing the temperature to which steel can be heated without injury?

20. What is the best fuel to be used in a reverberatory furnace?

21. How does steel differ from cast and wrought iron?

22. Does water in itself tend to promote combustion in a forge fire?

23. What will be the length of a spike made from a bar 2 inches in diameter and 6 inches long? The spike to be in the form of a cone 2 inches in diameter at the base.

24. Describe drop forging.

25. Below what temperature should the hammering not be carried when making a forging?

26. How does a cold-shut injure a piece of metal?

27. Which can be heated to the higher temperature without injury, iron or steel?

28. What is the difference in the effect between plunging red hot steel into oil and water?

29. How should the scale be removed from a forging during the several stages of its completion?

30. What is the weight of a bar of round iron $1\frac{3}{4}$ inches in diameter and 9 feet 10 inches long?

31. What will be the final length of a bar of iron 4 inches in diameter and 2 feet long, that has been drawn down to a diameter of 2 inches for a finished length of 2 feet? The bar will thus be 4 inches in diameter with one end 2 inches in diameter for a length of 2 feet.

32. What precaution should be taken when locating the welds of heavy shafts?

33. What effect does increase of the carbon in steel have upon the welding of the metal?

34. What are the fluxes used with iron and steel?

35. How does a reverberatory furnace differ from the ordinary forge?

36. What materials are used for casehardening?

37. What portion of a marine engine shaft is subjected to the heaviest stresses?

38. What are the principal tools used for heavy forging?

39. What is the weight of a wrought iron shaft 12 inches in diameter and 10 feet long having a hole 5 inches in diameter along its axis?

40. What should be the properties of a good blacksmith coal?

41. What is the common temperature at which iron and steel are worked?

42. What is the object of using a flux in welding?

43. How should the hammering of a long shaft be done? That is, how should the blows be distributed?

REVIEW QUESTIONS

ON THE SUBJECT OF

MACHINE SHOP WORK.

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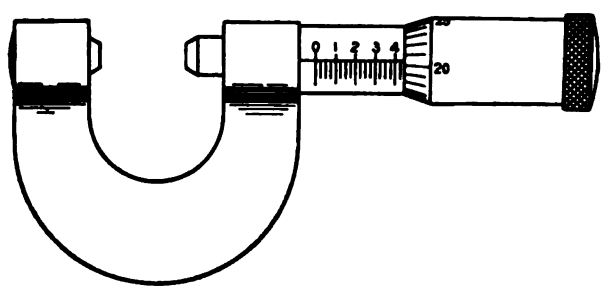
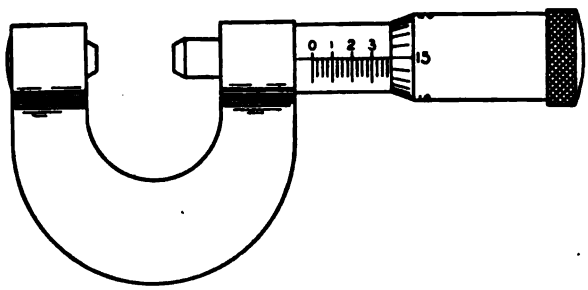
1. What are limit gauges?
2. When are calipers used? and how are they set?
3. If there are 40 threads per inch on the micrometer screw, what is the reading of this micrometer?



4. What is a soft hammer, and when is it used?
5. What is a chuck drill?
6. What methods are used for cleaning a file?
7. How should a file be held for fine filing?
8. Describe the surface gauge.
9. Describe the micrometer caliper.
10. Describe two common forms of chisel, and state under what conditions they are used.
11. Why is not the cutting surface of a file perfectly flat?

12. Give the reading of the micrometer caliper when in the position shown.

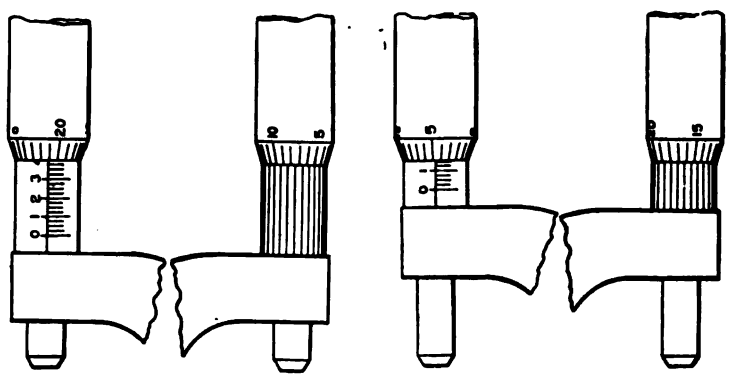


13. What methods are used for holding a file for filing large surfaces?

14. Describe the twist drill.

15. What is a vernier?

16. What is the reading of the vernier micrometer caliper when in the positions shown?



17. What is the result when the lips of the twist drill are of unequal length?

18. When are reamers used?

19. How much less should the diameter of the drilled hole be than finish size if a reamer is to be used?

20. Explain the methods of cutting screw threads with a die.

21. What advantage has an adjustable reamer over a solid reamer?

22. Describe the three styles of taps.

23. What size hole should be drilled, and what diameter of tap should be used, if the threads must fit a bolt having standard threads nine to the inch?

24. What is a jig?

25. Describe two kinds of templets.

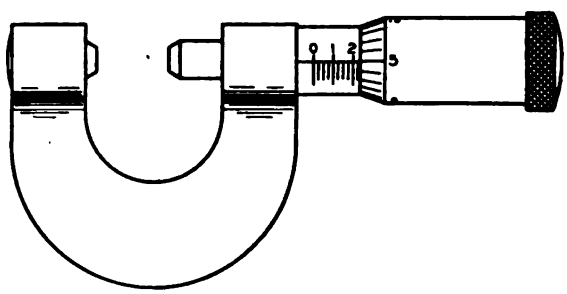
26. Should oil be used when chipping cast iron?

27. What should be the angle of a chisel for cutting wrought iron and steel?

28. What is a surface plate?

29. What is a center square?

30. Give the reading for the micrometer shown in the following illustration:—



31. What is a mandrel?

32. Describe the rise and fall rest.

33. How long will it take to turn a chip 18 inches on a shaft 24 inches long and $3\frac{1}{4}$ inches in diameter?

Assume cutting speed 20 feet per minute.

Assume feed $\frac{1}{50}$ inch per revolution.

34. Describe the process of making a taper fit.

35. The lead screw has a pitch of $\frac{1}{4}$ inch. What is the ratio of gears to be used to cut a screw with 18 threads per inch?

36. Describe the process of bringing the countersink back to center.

37. For what purpose is the back gear of a lathe?

38. Describe some method of adjusting pieces to center.

39. Describe the shapes and state the uses of the following lathe tools: Diamond point, side or facing tool, parting tool, and square-nosed tool.

40. Why are lubricants used in turning?

41. Describe the method for finding the clearance for a tool for cutting square threads.

42. On account of not having the proper gears at hand compound gears must be used. The lead screw has 4 threads per inch, and a screw having 9 threads per inch is to be cut. The gears chosen for drivers are of 24 teeth on the spindle gear and 30 on the intermediate. What gear should be used for the intermediate driven if the screw gear has 60 teeth?

43. Describe the U. S. Standard thread.

44. Describe the steady rest.

45. How would you adjust a piece to center if the hole must be run true?

46. Why should a boring tool have more clearance than a turning tool? Explain with sketch.

47. Explain the method of turning a taper by setting the tailstock over.

48. In what direction does the carriage run when cutting a right-hand thread?

49. A screw of 14 threads is to be cut in a lathe having a lead screw of 3 threads per inch. Compound gears are to be used. The gears available have 20, 30, 40, 50, 60, 70, and 80 teeth. What ones are to be used, and where?

50. How is motion transmitted from the cone pulley of a drill press to the drill?

51. How is motion transmitted from the spindle to the lead screw?

52. Describe clearance and rake as applied to a lathe tool. Give approximate values in degrees for cutting steel.

53. Should a tool for turning brass have rake? Why?

54. The end of a piston rod is to be turned tapering. The piston rod is 28 inches long; the tapered portion is to be 3 inches long. The diameters of the taper are to be $2\frac{3}{4}$ inches and $2\frac{5}{8}$ inches. How much must the tail block be set over?

55. Suppose the lead screw of a lathe has 4 threads per inch and we wish to cut 11 threads per inch. The gear on the spindle has 20 teeth. What gear should be chosen for the lead screw?

56. What is a universal radial drill?

57. In what ways is a twist drill preferable to a flat drill? How is the drill made to turn with the spindle?

58. Describe the universal chuck.

59. Why should not a tool be set too high?

60. How long will it take to turn a chip from a shaft 37 inches long $5\frac{1}{2}$ inches in diameter?

Assume cutting speed 23 feet per minute.

Assume feed of $\frac{1}{32}$ inch per revolution.

61. A connecting rod 5 feet 6 inches long is to be turned tapering. The taper is to extend from the center to the neck back of the stub ends. This distance is 23 inches. The diameter at the center is to be 3 inches, and at the neck $2\frac{5}{8}$ inches. Give the amount of set over for the tail stock.

62. The lead screw of a screw-cutting lathe has 3 threads per inch. The spindle gear has 18 teeth, and the screw gear has 66 teeth. How many threads per inch may be cut without altering the gears?

63. Explain some method of holding work on the drill press table.

64. Explain briefly the action of the planer.

65. What is interchangeable work?

66. Explain the method of grinding valves.

67. What is pickling?

68. Explain the reciprocating motion of a planer.

69. In what direction relative to the motion of the cutter should the work on a milling machine be fed?

70. What is the difference between pening and bending?

71. What is the difference in the rates of revolution given for surface milling of cast iron, with a surface milling cutter $3\frac{1}{2}$ inches in diameter, according to Addy's rule and the Brown & Sharpe table?

72. What is the chief difference between the ordinary planer and the plate planer?

73. What are the principal uses of the grinding-machine?

74. What is a surface plate? Describe the process of making.

75. Describe the hydrostatic level.

76. What is the principal difference between a shaper and a slotter?

77. What is the safe rate of revolution of an emery wheel 5 inches in diameter, if its surface speed is not to exceed 4,000 feet per minute?

78. A surface of cast iron is to be finished in one cut on the milling machine. The casting is 8 inches long and 5 inches wide. The milling cutter has a diameter of 3 inches and a width of 2 inches. How long will it take to do the work? Assume feed of $2\frac{1}{2}$ inches.

79. What is the principal advantage of the shaper?

80. What is a lap? Of what metal should it be made?

81. How may a permanent joint be made?

82. Describe in a general way the setting of a machine.

83. Explain the action of the tool in the slotter. How does it differ from the planer tool?

84. What should be the diameter of a piece as it comes from a lathe if it is to be ground to a diameter of 4 inches?

85. According to Addy, how long would it take to mill a cast iron surface 18 inches long, and 16 inches wide, with a milling cutter 6 inches in diameter and 3 inches wide?

86. What precaution must be observed in setting a tool on the planer?

87. How is a surface prepared for laying out work?

88. How are temporary joints made?

89. How many horse-power may be safely transmitted by a single belt 8 inches wide, running over a 36 inch pulley which makes 175 revolutions per minute?

90. State some of the uses of the milling machine.

91. How are case-hardened pieces usually finished?

92. What tools are used for laying out work? Explain the function of each.

93. Why should a lathe or planer tool work beneath the surface of a casting?

94. How may the power transmitted by the belt in Question 26 be increased to 32 horse-power?

95. According to Addy's rule, what should be the speed of a milling cutter 8 inches in diameter when working in cast iron?

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

1. Give the meaning of approximate and precise measurements. Give examples and reasons for employing either method when doing the individual piece of work.

2. When making single-lip drills why is it necessary to remove *exactly* one-half the diameter as shown in Fig. 19?

3. When making the taper reamer, called a stepped reamer (Fig. 51) why are the steps made straight rather than tapering?

4. When a mandrel is held in V blocks when laying off the center line as shown in Fig. 67, how would you find the *exact* location by precise measurements?

5. Why is it advisable to cut the threads of an adjustable tap somewhat smaller than the desired size for the tap to cut?

6. What would be the effect if a piece of work were turned to *finish* dimensions, when the live center of the lathe did not run true? If the dead center is not to gauge?

7. Why will a twist drill cut faster and make a truer hole than a flat drill?

8. State in your own language the result attained by using a reamer holder of the design shown in Fig. 58.

9. When extreme accuracy is required, why is it not advisable to grind the essential part of a milling machine arbor before it has the spline cut?

10. Why is it desirable for a tap to retain its correct pitch

when hardened? What would be the effect were it to elongate? What if it should contract?

11. How should a piece of round tool steel be centered for turning in the lathe?

12. Explain the method used to prevent a fluted reamer from chattering. What should be taken into consideration in designing the tooth?

13. When making mandrels, why should the center holes in the ends be deeper than in the case of most tools?

14. When is it allowable to cut the threads of a tap by means of a screw-threading die?

15. State in your own language the objection to reaming holes that *must* run perfectly true, and why it is considered allowable to ream a hole that is to be approximately trueas, for instance. the hole for receiving the tap in the tap holder shown in Fig. 105.

16. When is it advisable to use a high carbon tool steel? When a low? Give example.

17. When cutting the grooves in a reamer having 8 cutting edges, state the number of holes the index pin should be moved each time in order to get an uneven spacing that will diverge by 2° to 4° from an angle corresponding to equal spacing. Assume that the dividing head on the milling machine requires 40 turns of the index pin for one revolution of the spindle. If the pin is set in the circle having 20 holes.

18. What would be the result if the centers were not given the *extra* countersink, or recess cut as shown in Figs. 60 and 61?

19. Why should the lands of a hand tap be wider than those of a machine tap?

20. Why is it necessary to use a releasing tap holder when tapping holes where the threads go to, or nearly to the bottom of the hole?

21. What is the effect of uneven heating of tool steel for hardening? Why?

22. Why is it advisable to use a form of grinder having two *dead* centers when a piece of work is required exactly round?

23. Why should the center of a mandrel be lapped to an angle of 60° before the mandrel is ground to size?

24. What would be the result were the threads of a taper tap cut with the tail block set over to give the required taper?

25. Suppose a screw die hob were made with the same number of flutes and of the same proportions as hand taps. What would be the result if it were run into a screw thread die which had been provided with clearance holes?

26. When are *flat* drills used? Why?

27. When making the adjustable reamer shown in Fig. 47 what would be the result when it was hardened if the slots were cut to the *end* of reamer?

28. When making the sleeve for the expanding mandrel shown in Fig. 65, why should it not be held in a grinder chuck when grinding the hole to size?

29. Why should steel for a cutting tool be chosen somewhat larger than finish size?

30. Why is it necessary to reheat large pieces after they have been hardened?

31. Why is it not advisable to make the lands of screw threading dies wider than described? What is the result if they are made narrower?

32. Under what circumstances would you consider it advisable to use a counterbore, rather than a drill when enlarging a hole. Why?

33. Why would it not be considered good practice to turn the piece of stock represented in Fig. 131 to size before drilling the holes and working the slots to size?

34. Why is it not advisable to make a hollow mill to be used in roughing out work, having more than 4 teeth?

35. Why is it advisable to give a finish hollow mill more than 4 teeth?

36. When hardening a hollow mill of the form shown in Fig. 147, why is it advisable to dip it in the bath with the cutting edges uppermost?

37. Why is it necessary using a forming tool to have the face of the tool at the height of the center?

38. Give the advantages derived from using a forming tool and holder of the design shown in Fig. 162.

39. Why is a milling machine cutter more liable to crack when hardening than other forms of tools?

40. Why is it not good practice to ream holes in milling machine cutters to finish size?

41. What is the result when a milling machine cutter is in use if the hole does not fit the arbor?

42. When is it advisable to use milling machine cutters having interlocking teeth?

43. When is it advisable to use milling machine cutters having their teeth cut spirally? Why?

44. When is it advisable to cut the teeth of milling machine cutters with a right-hand spiral? When a left-hand spiral? Why?

45. State advantage gained in making milling machine cutters with nicked teeth.

46. Why is it generally considered advisable to make milling machine cutters that are larger than 6 or 8 inches diameter with inserted teeth.

47. When a blank for a milling machine cutter that is to have inserted teeth is milled with slots that are at an angle to the cutter axis, why is it not advisable to leave the faces of the teeth at that angle?

48. If an emery wheel, 3 inches in diameter, is used in grinding the teeth of a milling machine cutter, how many revolutions must it make in a minute in order to run at a peripheral speed of 5,000 feet per minute?

49. Why is it not generally considered good practice to make key ways in milling machine cutters with sharp corners?

50. State in your own language the generally accepted meaning of the term "formed cutter" of form cutter.

51. Name some of the advantages derived from the use of formed cutters.

52. What would be the result if the faces of the teeth of a formed mill were not recut after they were backed off?

53. When backing off the teeth of a formed mill, what would be the result of setting the forming tool above or below the center of the work?

54. When making milling machine cutters with threaded holes, why is it necessary to first thread the blank, then machine it on a threaded mandrel?

What would be the result were the cutter machined to shape before threading the hole?

55. When machining a piece of work having a threaded hole, why is it not advisable to screw the piece on to a threaded mandrel in such a manner that the shoulder of work is against the shoulder of mandrel when squaring the first end?

56. When are fly cutters used? Name some of the advantages of using them where they will answer the purpose.

57. When are end mills used?

58. Why are collets used in holding end mills?

59. Why is it advisable to turn, or grind the shanks of end mills after the mills are hardened?

60. When grinding the teeth of milling machine cutters for clearance, what is the result if the angle of clearance is too great? What if it is not sufficient?

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